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Monthly  
**Bulletin**  
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(English Edition)





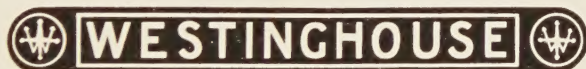
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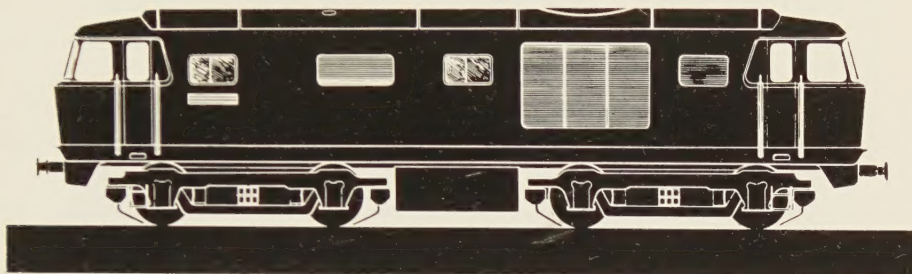
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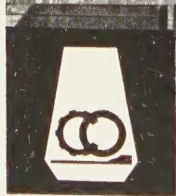
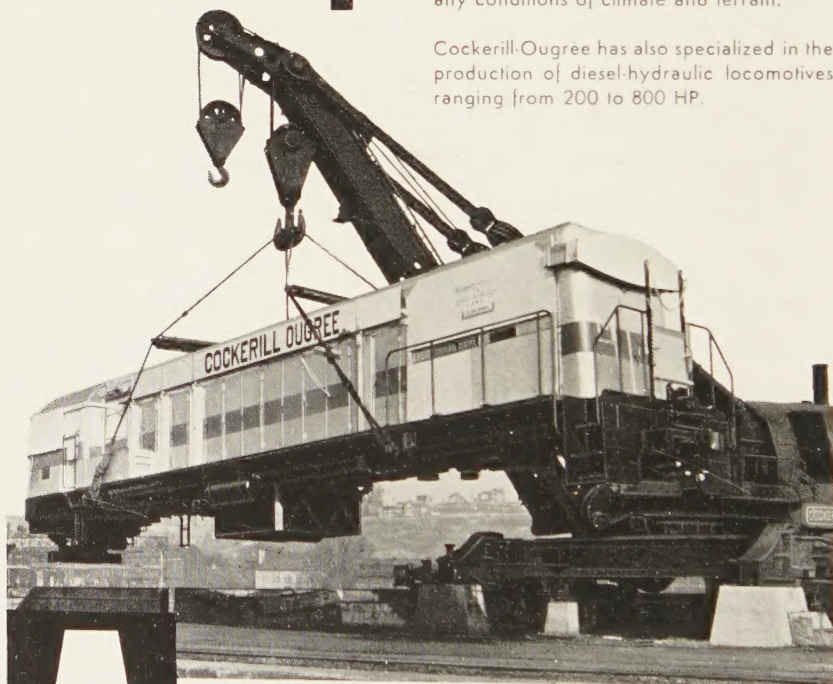
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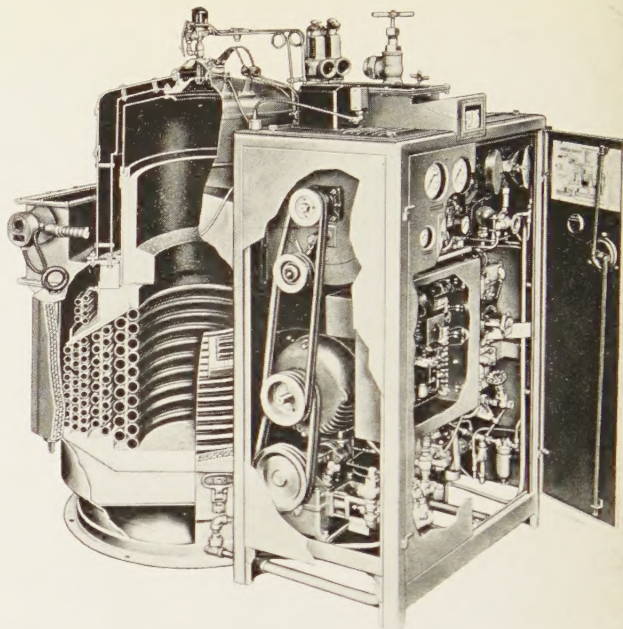
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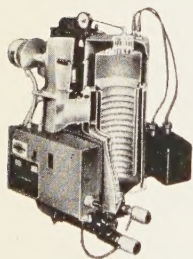
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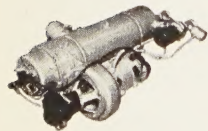


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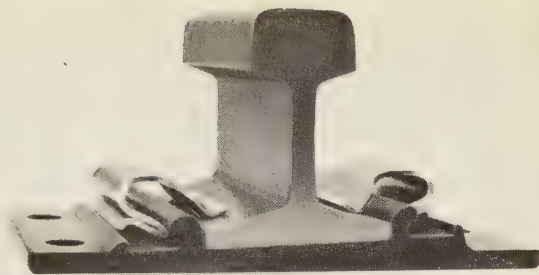
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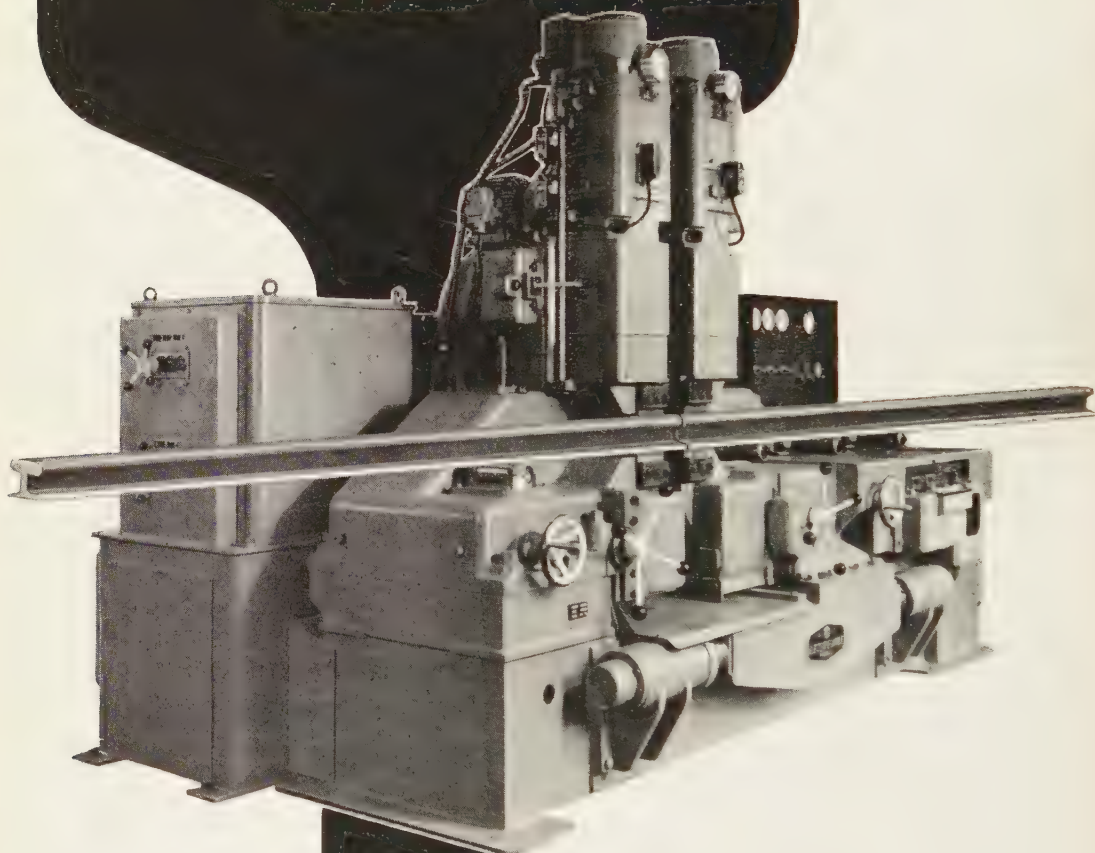
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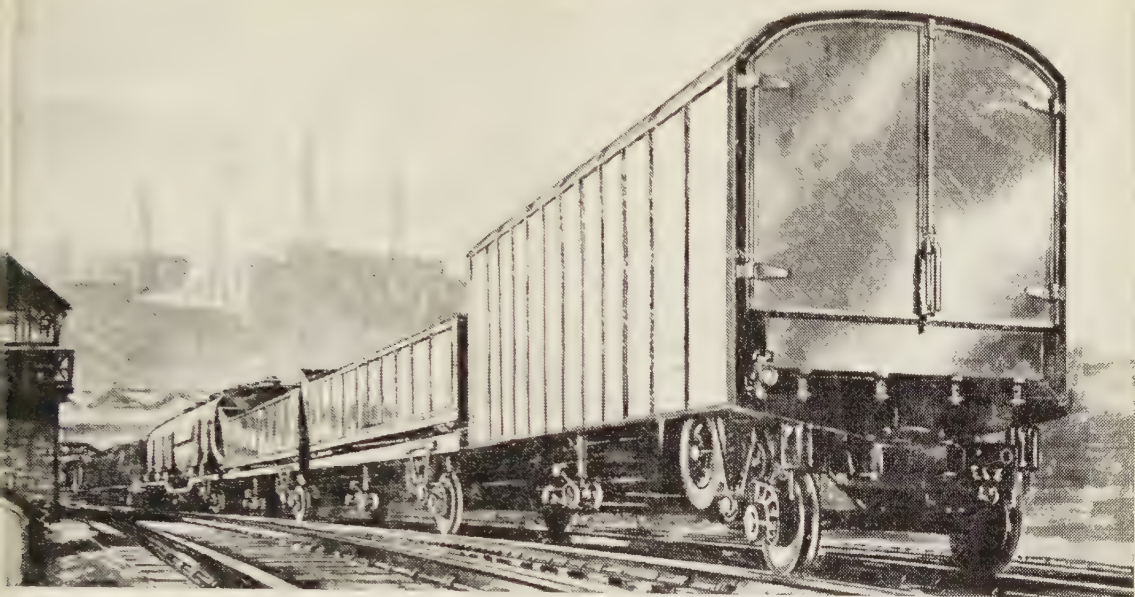
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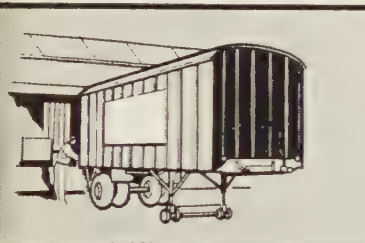
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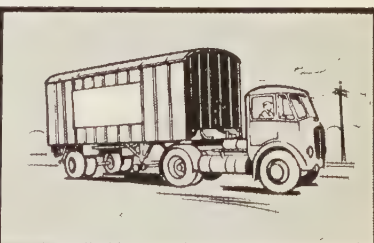
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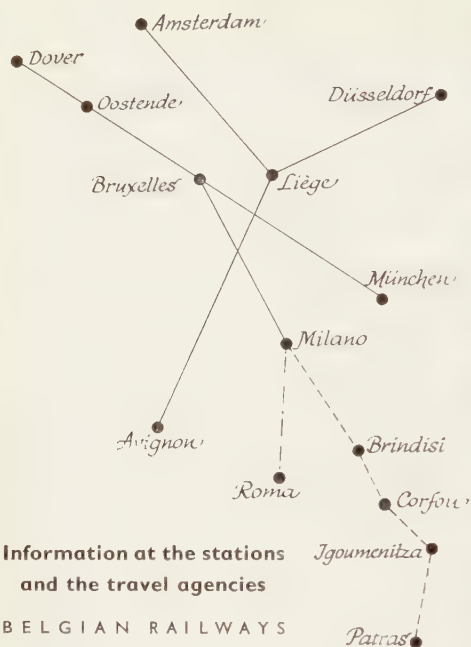
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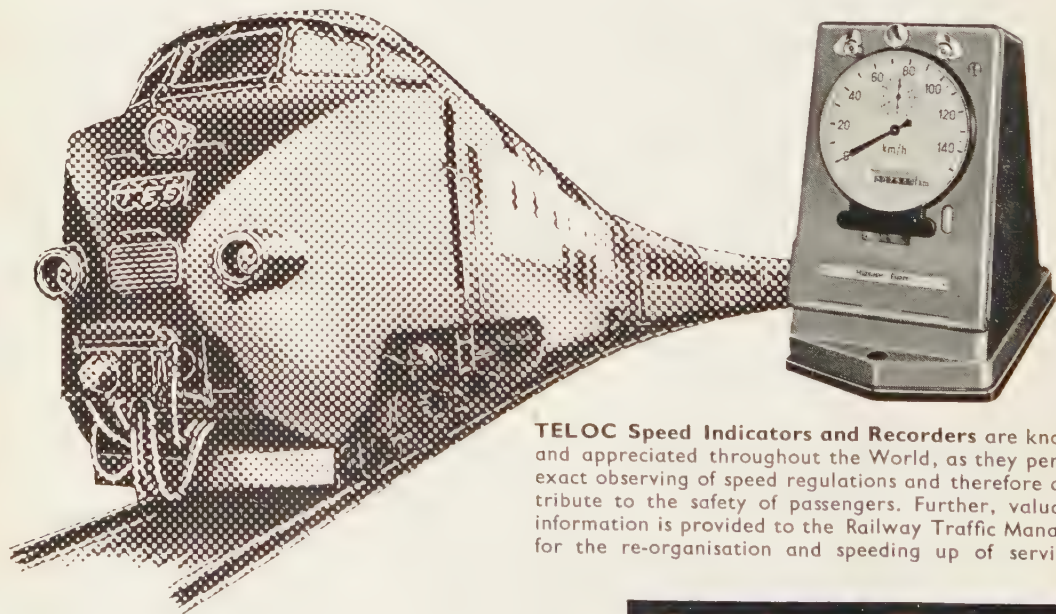
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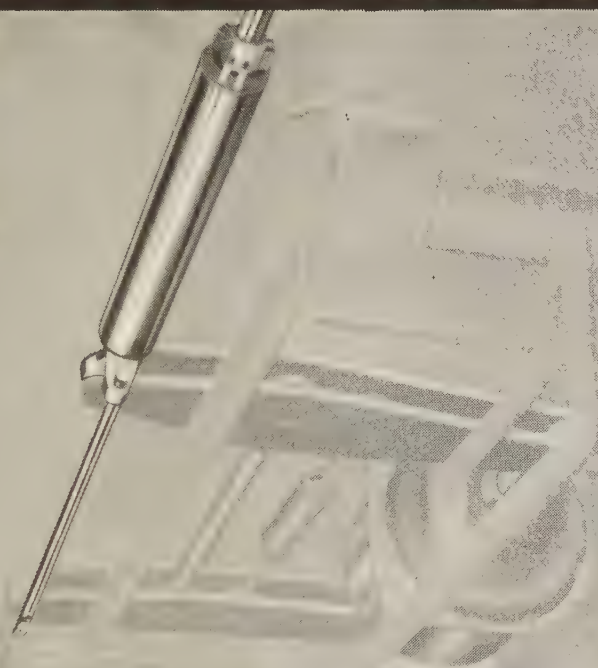


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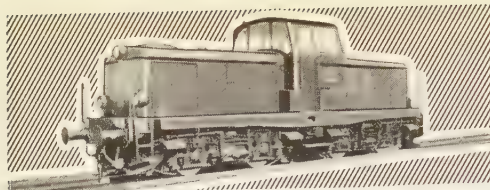
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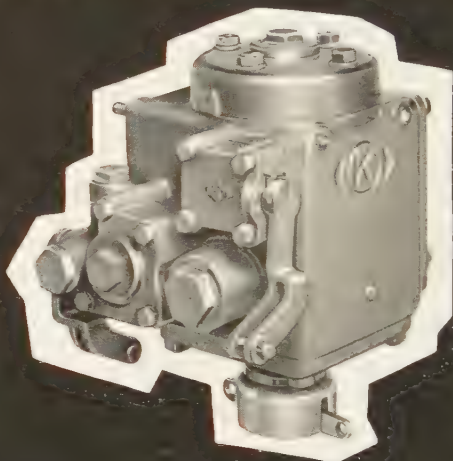


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**BULLETIN**  
OF THE  
**INTERNATIONAL RAILWAY CONGRESS**  
ASSOCIATION  
(ENGLISH EDITION)

[ 625 .251 ]

## Derivation of initial speeds and stopping distances from deceleration/time curves,

by J. LAW, B.Sc., A. Inst. P., Assoc. I. Loco. E.

Railway Research Department, Ferodo Ltd.

Essentially brake testing involves the measurement of deceleration. This can be obtained by direct means or by calculation knowing the initial speed, stopping distance, and stopping time. For road vehicles tests can be designed to suit particular features under investigation and any distance measurements can be taken with the minimum of interference to other traffic.

The situation on the railways is very different: tracks maintained solely for test purposes are few and far between, whilst traffic densities militate against the use of main line stretches for anything more than the briefest periods. Test trains must be integrated with normal schedules, often allowing insufficient time for all the relevant data to be collected during actual test runs. There is therefore a strong case for using instrumentation which records all essential information.

To the traffic manager stopping time is of prime importance as seconds lost in braking could seriously affect track utilisation in dense suburban areas. The signal

engineer, the brake engineer, and the block manufacturer on the other hand are all concerned with stopping distance, although each for a slightly different reason. The siting of signals has to be such that trains travelling at the maximum permitted speed for a section can stop in the prescribed distance. A brake engineer calculates the braking efficiency of a train from the point where the driver moves his brake handle, whilst a block manufacturer is interested mainly in braking efficiency based on the distance travelled from the moment the blocks come into contact with the wheels.

Methods currently employed for obtaining stopping distances rely either on physical measurement between start and finish markers, the use of a premeasured track, or calculation from the counted revolutions of a freely running wheel of known diameter. Stopping times are measured with a stop watch and initial speeds either from a cab speedometer, or by timing the passage of the train between adjacent quarter-mile posts prior to making the brake application.

The method to be described involving the use of a recording decelerometer and stopwatch only gives a full assessment of the braking performance, and since no electrical or mechanical connection with the test vehicle is required has the obvious advantage of permitting tests on any rake at any time without previous preparation.

Recording decelerometers consist mainly of an inertia system in which a spring

evolved which is put forward in the hope that it may be of use to others engaged in this type of work.

Consider the case of a vehicle being braked to rest from an initial speed  $u$ , in time  $T$ , the stopping distance being  $S$ .

At any time  $t$  the velocity is  $v$  :

$$S = \int_0^T v dt.$$

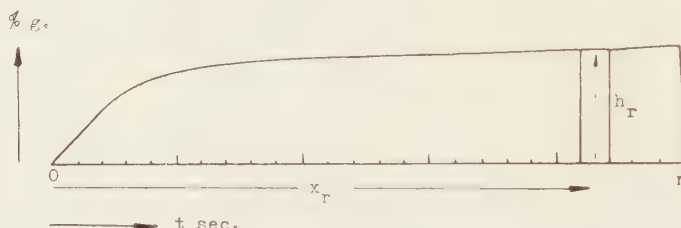


Fig. 1.

supported mass actuates a pen whose deflection is proportional to deceleration. On the model used this deflection is recorded on a motor-driven tape, a time base being superimposed by a second pen operated by a half second make-and-break circuit, and for each stop a deceleration/time curve is obtained similar to that shown in figure 1.

Stopping time and the deceleration at any time during the stop can be read directly from the trace, and since the area under the deceleration/time curve is a measure of the initial speed, the average deceleration throughout the stop can be obtained from the height of the rectangle of equal area constructed on the same base line.

The derivation of stopping distance from the deceleration/time curve is by no means so obvious and a procedure has been

This may be integrated by parts so that :

$$S = \left[ vt \right]_0^T - \int_{t=0}^{t=T} t dv.$$

When  $t = 0$ ,  $vt = 0$ , and at  $t = T$ ,  $v = 0$ .

$$S = \int_0^T t \left( - \frac{dv}{dt} \right) dt.$$

This expression is the first moment of area of the deceleration/time curve about the ordinate  $t = 0$  since  $- dv/dt$  is the value of deceleration at any time  $t$ .

In cases where the deceleration is a known function of  $t$  the stopping distance can be obtained by direct integration,

e.g. when  $-\frac{dv}{dt} = at^{1/2}$ ,  $S = 2/5 aT^{5/2}$

which can easily be verified from first

principles by inserting the correct constants of integration.

In practice because full brake power is not available instantaneously and because deceleration may be dependent on velocity, the deceleration cannot be expressed as a simple function of  $t$ , and the first moment

The stopping distance in feet is then obtained from the first moment of area by converting the vertical scale to ft/sec and the horizontal scale to seconds. One second intervals are found to give reasonable accuracy, and considerably ease the computation since by making  $h_r$  the height

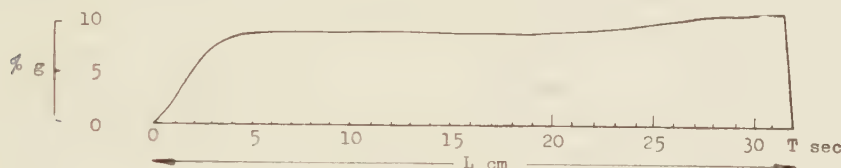


Fig. 2.

$$L = 12.7 \text{ cm};$$

$$\text{Area under the curve} = 22.0 \text{ cm}^2;$$

$$\text{Vertical scale } 1 \text{ cm } (= 5\% g) = 1.1 \text{ m.p.h./sec};$$

$$\text{Horizontal scale } 1 \text{ cm} = \frac{1}{L} \text{ sec};$$

$$\therefore 1 \text{ cm}^2 = 1.1 \frac{T}{L} \text{ m.p.h.};$$

$$\begin{aligned} \text{and initial speed} &= 22 \times 1.1 \times \frac{32}{12.7} \text{ m.p.h.}; \\ &= 61 \text{ m.p.h.} \end{aligned}$$

of area is obtained by summing the products of the small trapezoidal areas and appropriate values of  $t$  in the following way.

In figure 1, if the deceleration/time trace is divided up into  $n$  equal intervals where  $h_r$  is the height at the midpoint of each interval, and  $x_r$  is the distance of this midpoint from the point  $t = 0$ , then the first moment of area about the origin,  $A_1$  is given by :

$$A_1 = \sum_1^n x_r h_r \dots \dots (1)$$

at successive seconds Equation 1 transforms to :

$$A_1 = a + \sum_{n=1}^{n=T-1/2-k} n h_n + b$$

$$\text{where : } a = \frac{h_{0.25}}{4};$$

$T$  = the total stopping time in seconds;

$k$  = a fraction lying between zero and  $1/2$ ;

$$\text{and } b = z h_z \text{ where } Z = T - \frac{k+1}{2}.$$

If stopping times are measured to the nearest half second as in the author's case then  $k$  takes on the value 0 or 1/2 depending on whether  $T$  is an odd or even number of half seconds.

A typical example is worked out below. Figure 2 shows a recorded deceleration/time trace for a 4 car suburban unit. The initial speed as given by the cab speedometer was 60 m.p.h. and the stopping time measured by a stopwatch from the time of operation of the driver's brake valve to coming to rest was 32.5 sec.

### Stopping distance.

$t_{sec}$	$-\frac{dv}{dt} (\% g)$	$-t \frac{dv}{dt} dt$ ( $\% g \times sec^2$ )
0.25	0.5	0.1
1	2.0	2.0
2	4.5	9.0
3	7.2	21.6
4	8.5	34.0
5	9.0	45.0
6	9.0	54.0
7	9.0	63.0
8	9.2	73.6
9	9.2	82.8
10	9.0	90.0
11	9.2	101.2
12	9.2	110.4
13	9.2	119.6
14	9.2	128.8
15	9.2	138.0
16	9.0	144.0
17	9.2	156.4
18	9.3	167.4
19	9.3	176.7
20	9.2	184.0
21	9.3	195.3
22	9.5	209.0

23	9.8	235.4	
24	10.0	240.0	
25	10.0	250.0	
26	10.2	265.2	
27	10.6	286.2	
28	10.7	299.6	
29	10.9	316.1	
30	11.0	330.0	
31	11.1	344.1	
31.75	11.2	0.5	177.8

$$\sum t \left( -\frac{dv}{dt} \right) dt = 5050.4$$

$$0.322 \text{ ft/sec}^2 = 1\% g$$

$$\therefore S = 5050.4 \times 0.322 = 1626 \text{ ft.}$$

The stopping distance measured by a 60 foot tape between start and finish markers for this stop was 1644 ft.

The difference between the brake application time from the stopwatch and the block application time from the deceleration/time trace was 0.5 sec. Since at 60 m.p.h. a train travels 44 ft in half a second, the calculated stopping distance would be  $1626 + 44$  or 1670 ft. The difference of 26 ft between the calculated distance and the measured distance is approximately half a coach length.

It is interesting in conclusion to summarise all the quantities measured during a typical braking test and to asterisk those which fall within the compass of a recording decelerometer.

### 1. Stopping time.

- (a) From the time the driver's brake is applied to coming to rest. Stopwatch.

(b) \* From the time the deceleration commences to coming to rest.

2. \* **Initial speed.**

3. **Stopping distance.**

(a) (†) From the time the driver applies his brake to coming to rest.

(b) \* From the time deceleration commences to coming to rest.

(†) *Note.* — It is possible to obtain 3(a) by multiplying the initial speed in ft/sec by the time lag in seconds between the

brake handle being moved and the brakes actually contacting the wheels, and adding this quantity to 3(b).

The success of the method has been proved over a number of train tests where independent measurements of speed and distance have been available.

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# Operational research applied to centres where goods trains are divided up and made up.

## Statistical-mathematical spacing of train departures from a marshalling yard,

by Dr.-Eng. Filippo BORDONI,

in collaboration with Dr.-Eng. Carlo D'AGOSTINO and Dr.-Eng. Adelmo DAVITE.

(Ingegneria Ferroviaria, May 1960.)

**SUMMARY.** — *The spacing of train departures from a marshalling yard must as far as possible meet the condition of minimum average stabling time for the wagons on the marshalling sidings.*

*To solve this problem, a statistical-mathematical method has been devised which might replace, or at least contain the empirical method now used.*

*The theory developed makes it possible, amongst other things, to appreciate that equal intervals between train departures are only necessary when there is a more or less constant division of the traffic on arrival, which is hardly ever found in practice.*

*It is obvious that the making up of the trains on departure should be studied as a function of the traffic requirements, as well as of the loading and unloading of the wagons, but even in this case the statistical-mathematical process in question lends itself to supplying useful information for improving the average time the wagons remain in the yard, and finally the turn round of the wagon and the delivery of the goods.*

1. — Railway operating experts know that marshalling yards can all be represented by one diagram, showing essentially :

- sidings for incoming trains, arranged in one or more sets (reception sidings : FA);
- sorting sidings, also grouped into one or more sets (sorting sidings : FD);
- train formation sidings, which might be part of the sorting sidings or be independent (train formation sidings : FB);
- train departure sidings, grouped in one or more sets, and in the simpler installations, also connected to the sorting set (departure set : FP).

The operating of a marshalling yard can be considered as an organisation problem, represented by the realisation of a given daily programme which, apart from special supplementary operations, which we shall not take into account, consists essentially in assuring the arrival and sorting of a certain

number of trains in order to assure given services by making up a certain number of trains from the centre.

The wagons (loaded or empty), the component elements of the services provided for in the operating programme of a marshalling yard, undergo between arrival and departure a given succession of operations, possibly preceded by waiting times. For all these, there is a corresponding time for carrying out the operation and for waiting, which together account for the time spent by the wagon in the marshalling yard.

The operations and waiting periods can be classified chronologically as follows :

- waiting time, in FA, before the operation of preparation for sorting;
- operation of preparing for sorting;
- waiting time in FA for the operation of sorting;
- operation of sorting and putting into position;

- waiting time, in FD, to prepare the operation of collecting;
- operation to prepare collecting; waiting time, in FD, for the operation of collecting;
- operation of collecting, reclassification (if necessary) and making up;
- waiting time, in FP, for the operation of preparing for departure;
- operation of preparing for departure;
- waiting time in FP before departure.

We will designate by :

- $T_{pl}$  the time taken for the operation of preparing for sorting;
- $T_l$  the time taken for the operation of sorting;
- $T_e$  the time for collecting, reclassification and making up (including also the time taken for the operation of preparing for collecting);
- $T_{pp}$  the time taken for the operation of preparing for departure;

and by :

- $T_a^{FA'}$  the average waiting time before the operation of preparing for sorting;
- $T_a^{FA''}$  the average waiting time before the operation of sorting;
- $T_a^{FD}$  the average time of waiting for the operation of collecting;
- $T_a^{FP}$  the average waiting time before the operation of preparing for departure.

Whereas for the determination of the times of operation  $T_{pl}$ ,  $T_l$ ,  $T_e$  and  $T_{pp}$ , use is generally made of the results of statistical enquiries, by timing on several occasions the different operations carried out, the average waiting times  $T_a^{FA'}$ ,  $T_a^{FA''}$ ,  $T_a^{FD}$  and  $T_a^{FP}$  are calculated from theoretical considerations, using mathematical theories integrated with statistical methods.

The average waiting times and the operation times defined above form the characteristic parameters of a marshalling yard.

For reasons of convenience, the cycle of operations carried out in a marshalling yard is divided up into two distinct phases, grouping in one of these all the operations (and corresponding waiting times) from arrival until knocking off (including bringing up) and in the second phase all the operations (and corresponding waiting periods) between collection and departure. The first phase, therefore, covers the operations of preparation before sorting, the operation of sorting, waiting time before this preparation, and waiting time before sorting, whilst the second phase includes the operation of making up (including, as has already been stated, preparation before being made up, regrouping and collection), the operation of preparation for departure, waiting to be collected and waiting to depart.

The total operation time :

$$S^* = T_{pl} + T_l + T_e + T_{pp}$$

(interval of time below which the handling of any wagon dealt with in the yard cannot fall) can thus be subdivided into two parts :

- the operation time  $S_1^* = T_{pl} + T_l$ , relating to the first phase;
- the operation time  $S_2^* = T_e + T_{pp}$  relating to the second phase.

In the present study, which relates in practice to the whole cycle of operations carried out in a marshalling yard, it is necessary to suppose that the phenomena concerning the marshalled wagon (wagon leaving the marshalling yard which has undergone between arrival and departure the stipulated succession of operations) have a periodic character and respect the principle of continuity.

Consequently, we have to admit the validity of the two fundamental principles :

- the phenomena are repeated in a 24 hour cycle  $\vartheta^*$  (principle of periodicity);
- in each period  $\vartheta^*$  the number of wagons leaving is equal to the number of wagons arriving (principle of continuity).

2. — As we have already indicated, the wagons (loaded or empty) which arrive at a

marshalling yard have to be classified according to the services they will form part of on departure, meaning by service the destination of the wagons, which are grouped according to a predetermined routing programme. Destination is to be understood in a wide sense : it may represent a single centre (loading, unloading or marshalling point), or a group of centres in the same main direction.

To get out the services programme of a marshalling yard, certain given logical criteria are used, based on experience, naturally taking into account the destination and the number of wagons on arrival. Each direction radiating from the marshalling yard forms an individual field of research and can be dealt with separately. When examining a certain direction, the succession of centres absorbing or forwarding wagons in the direction in question which are to be considered as important centres is fixed, understanding by absorbing not only local units but also wagons in transit which are not going on as far as the next centre. Making use of the results of accurate statistical enquiries on the arrival trains, it is possible to group the data in graphs or direction tables which bring out the elements needed for studying the services.

The services programme must be got out in principle in such a way as to obtain with a sufficient volume of traffic the greatest possible number of long runs. Therefore, first of all, the fast runs must be determined (long runs), then the through services (average runs) and finally the stopping services used for delivering consignments all along the line.

The whole series of wagons for a service, when making up a train, are called the « lot ». Trains may consist of one or more lots. As far as possible, the largest possible number of trains must be made up of single lots (single service) for long runs.

The number of trains made up in a marshalling yard is obviously limited by the number of sidings available in the sorting sets (FD), which are known as the direction fan in the yard.

The most suitable programme is obviously

that allowing of a single FD siding for each individual train, because grouping several trains on the same siding involves a further regrouping of the wagons and subsequently sorting them according to the train to which they belong.

The actual distribution of the arriving trains in a yard depends on a whole series of reasons which it is practically impossible to take into account individually.

The main motives which affect the distribution of arriving trains are :

- conditions laid down on departure from the starting station, such as load to be completed and to await the arrival of a sufficient number of wagons to make a complete train load;
- traffic conditions on the line the train is going to use, which depend above all on the passenger train requirements, and possible interruptions due to inspection and maintenance work on the lines;
- working in with connections at the junction stations to take off lots of wagons belonging to the services worked by the train in question;
- delays, sometimes appreciable, to which goods trains are often subjected.

To study the spacing of trains leaving, it is necessary to consider the most likely distribution of trains arriving, taking into account the actual time of arrival of those trains which run most frequently, and determining the existing services covered by each train by means of statistical studies. In this way, it is possible to prepare a diagram which clearly shows for each train the composition (existing services and their extent) and the most probable time of arrival.

The waiting time at FD for the collecting operations (including the operation of preparing for collecting) varies from one lot of wagons to another, because though knocking off takes place successively, collecting only takes place when the train is complete, once or several times a day, according to the number of trains leaving for each service. We have to take the average times, because, whereas the average waiting time in FA and FP as a general rule applies

to the whole set of sidings, in the case of FD it is necessary to take into account the average waiting time per train service, and consequently for each individual FD siding. This average time depends not only on the distribution and average statistical composition of the trains on arrival, but also on the spacing of the trains leaving.

For greater simplicity, we will take it that the operation of collecting begins when the last wagon completing the service to be got ready for departure comes onto each of the FD sidings.

The time awaiting making up on FD after collecting the final lot of wagons must be considered as lost time which in principle should be avoided. Likewise, the time awaiting departure can also be considered as lost time (once the operation of preparation for departure has been completed). In the mathematical development we are going to set out, we can therefore consider these times as being zero or at any rate negligible. This hypothesis is always acceptable in a type study, amongst other reasons because the rational organisation of a marshalling yard should always take care to avoid such lost time. In any case, there is nothing to prevent it being included in the final formula by adopting a suitable coefficient of correction.

3. — We have stated that the average waiting time on FD should be based on each service made up on each individual siding, and as it is easy to see, this average time depends :

- on the distribution of trains arriving which include wagons for the service in question;
- on the number of wagons for the service on each arriving train;
- on the spacing of the trains leaving which can include wagons for the run in question, seeing that this spacing determines the distribution of the made up lots on FD.

Let us take a given service I, on a given siding of FD; we wish to determine the average waiting time  $T_a^{FD}$  starting with the following simplified hypothesis :

- the waiting time before the operation of collecting the last wagon coming onto the FD siding to make up the train I is zero;
- we are to take as valid the principles of periodicity (period  $\vartheta^* = 24$  hours) and continuity (the number  $Q_i$  of wagons for the service in question coming in during the period  $\vartheta^*$  is equal to the number of wagons leaving in the same period);
- that the trains leaving which will take wagons for service I are all made up of an equal number  $q$  of wagons.

Let us designate by :

- 1, 2, ...  $n$  the chronological succession of all the  $n$  trains arriving which include one or more wagons for service I;
- $\vartheta_1, \vartheta_2 \dots \vartheta_n$  the average statistical value of the real times of arrival of each train 1, 2, ...  $n$ ;
- $A_1, A_2, \dots A_n$  the average statistical value of the number of wagons for service I on the trains 1, 2, ...  $n$ .

#### First case :

$$Q_i = \sum_{h=1}^{h=n} A_h \cong q,$$

in other words the number of wagons for service I coming in during a period  $\vartheta^*$  is more or less equal to the composition of a train.

In this case, it is sufficient, for the service in question, to provide a single train leaving the marshalling yard for each period  $\vartheta^*$  and consequently only one collection on FD is needed.

Taking it that this period starts at 0 hours (see fig. 1) of a given day and that the single train leaving has to pick up as its last lot that of train  $r$  arriving at  $\vartheta_r$  o'clock, with  $A$  wagons for service I, and if we allow the hypothesis already stated that the time of waiting for this making up operation is zero, the time the stock is assembled can be expressed by the formula :

$$\begin{aligned} \vartheta_e &= \vartheta_r + T_a^{FA'} + T_a^{FA''} + T_{pl} + T_l \\ &= \vartheta_r + T_a + S_1^*, \end{aligned}$$

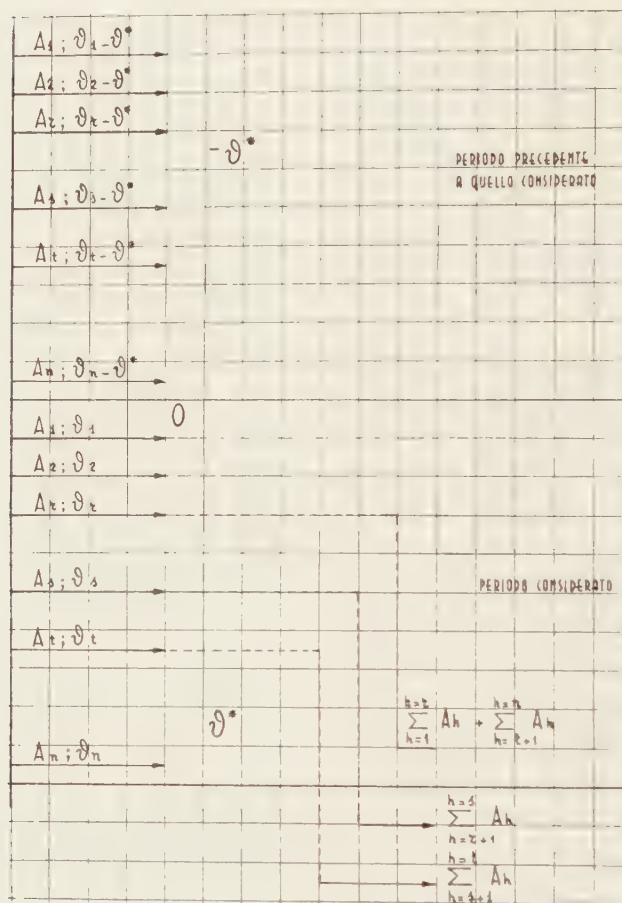


Fig. 1.

N. B. — Periodo precedente a quello considerato = period prior to that under consideration. — Periodo considerato = period under consideration.

in which we have put :

$$T_a = T_a^{FA'} + T_a^{FA''}; S_1^* = T_{pl} + T_l.$$

In other words, the time of collection on FD is delayed compared with the arrival time  $\vartheta_r$  of the last lot  $A_r$  by an amount equal to the sum of the average waiting time

on FA and the time taken for the operation of arriving at the sorting point (including bringing up) belonging to the first phase of the cycle of operations carried out in the sorting sidings.

Consequently the average time of waiting on FD amounts to :

$$T_a^{FD} = \frac{\sum_{h=1}^{h=r} [(\vartheta_r + T_a + S_1^*) - (\vartheta_h + T_a + S_1^*)] A_h + \sum_{h=r+1}^{h=n} [(\vartheta_r + T_a + S_1^*) - (\vartheta_h + T_a + S_1^* - \vartheta^*)] A_h}{Q_t}$$

a formula which represents the average increased by the waiting time on FD of  $n$  lots  $A_h$  of the service I; the first index figure of the sum of the numerator relates to  $r$  lots which have come in on the day in question, the second sum on the contrary to  $n - r$  lots which came in the previous day.

Simplifying, we get :

$$T_{aFD} = \vartheta_r - \frac{\vartheta^*}{q} \sum_{h=1}^{h=r} A_h + \vartheta^* - \vartheta_o^*, \quad (1)$$

in which  $\vartheta_o^*$  can be defined as the barycentric time of arrival of service I, which is equal to the expression :

$$\vartheta_o^* = \frac{\sum_{h=1}^{h=n} A_h \vartheta_h}{Q_i}$$

If we make abstraction of all other considerations, the most suitable time at which to assemble the wagons is that which reduces the average waiting time on FD to the minimum. It is therefore necessary to determine the value  $\vartheta_r$  of  $\vartheta_r$  which will make the value of the function (1) minimum.

As  $\vartheta^*$  and  $\vartheta_o^*$  are independent of  $\vartheta_r$ , it is necessary to reduce to the minimum :

$$f(\vartheta_r) = \vartheta_r - \frac{\vartheta^*}{q} \sum_{h=1}^{h=r} A_h \quad (2)$$

in which  $\vartheta_r$  is the independent variable, which can take the  $n$  values :  $\vartheta_1, \vartheta_2, \dots, \vartheta_n$ .

This problem of the minimum can be solved by a graphical method.

For greater convenience, it is advisable to multiply the second member of (2) by the constant  $q/\vartheta^*$ . The function to be reduced to the minimum thus becomes :

$$f_1(\vartheta_r) = \vartheta_r \frac{q}{\vartheta^*} - \sum_{h=1}^{h=r} A_h. \quad (2')$$

The relation (2') can be considered as the difference of two functions :

$$y_1 = \vartheta_r \frac{q}{\vartheta^*}; \quad y_2 = \sum_{h=1}^{h=r} A_h.$$

Function  $y_2$  is represented by a stepped diagram and  $y_1$ , by a short straight line passing through the origin of the coordinates and forming with the axis of the abscissae an angle the trigonometrical tangent of which is  $q/\vartheta^*$ . As after a period  $\vartheta^*$ , the total number of wagons for service I which have come into the yard is equal to  $q$ , the straight line must join up with the stepped diagram of  $y_2$  at the point of the coordinates  $(\vartheta^*, q)$ .

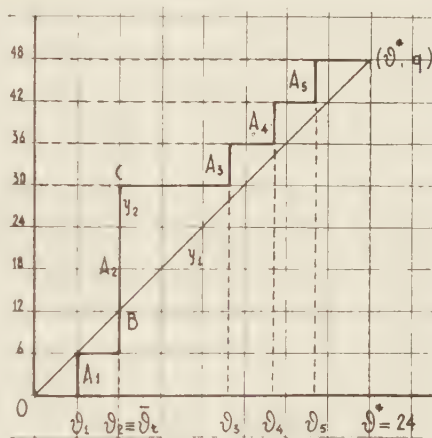


Fig. 2.

In figure 2 the two functions  $y_1$  and  $y_2$  have been represented under the hypothesis:

$n = 5$ ;  $\vartheta^* = 24$ ;  $q = 48$ ;  $A_1 = 6$ ;  $A_2 = 24$ ;  $A_3 = 6$ ;  $A_4 = 6$ ;  $A_5 = 6$ ;  $\vartheta_1 = 3$ ;  $\vartheta_2 = 6$ ;  $\vartheta_3 = 14$ ;  $\vartheta_4 = 17$ ;  $\vartheta_5 = 20$ .

If we examine the live divergencies :

$$\Delta_r = y_1 - y_2; \quad r = 1, 2, 3, 4, 5,$$

the value of  $\vartheta_r$  corresponding to the minimum divergence (maximum absolute value of the negative divergencies, or, if this be not

so, minimum value of the positive divergencies) represents the time  $\vartheta_r$  of arrival of the train which brings in the last wagon for the single train leaving in order to make the average waiting time  $T_a^{FD}$  :

$$T_a^{FD} = \overline{\vartheta_r} - \frac{\vartheta^*}{q} \sum_{h=1}^{h=r} A_h + \vartheta^* - \vartheta_o^*.$$

Consequently :

$$\vartheta_e = \overline{\vartheta_r} + T_a + S_1^*.$$

Figure 2 shows that BC is the maximum absolute value of the negative divergencies; it follows that  $\vartheta_r \equiv \vartheta_2$ . From this, it can be deduced that lots  $A_3$ ,  $A_4$ , and  $A_5$  came in on the previous day.

### Observation.

If we have :

$$Q_i = \frac{1}{2} q; \quad Q_i = \frac{1}{3} q \dots,$$

we can proceed in an absolutely analogous manner to determine  $\vartheta_r$ , on condition that we make  $\vartheta^* = 48$ ,  $\vartheta^* = 72$ , etc.

From this we can calculate the values of  $T_a^{FD}$  and  $\vartheta_e$  which apply to the periodic trains.

### Second case :

$$Q_i = \frac{h=n}{h=1} A_h \cong 2q.$$

in other words, the number of wagons for service I arriving in a period  $\vartheta^*$  is more or less equal to the composition of two trains. In this case, it is sufficient for this service to provide two trains leaving the marshalling yard for each period  $\vartheta^*$ , carrying out two collections on FD.

If we designate by  $\vartheta_r$  and  $\vartheta_s$  the times of arrival of the last lots  $A_r$  and  $A_s$  intended respectively for the formation of the first and second trains, we should have :

$$\sum_{h=r+1}^{h=s} A_h \cong q; \text{ whence: } \sum_{h=1}^{h=r} A_h + \sum_{h=s+1}^{h=n} A_h \cong q.$$

The hour for assembling the rolling stock will be :

— for the first train :

$$\vartheta_{e1} = \vartheta_r + T_a + S_1^*;$$

— for the second train :

$$\vartheta_{e2} = \vartheta_s + T_a + S_1^*.$$

The average waiting time is consequently :

— for the first train :

$$T_{a1}^{FD} = \frac{\sum_{h=1}^{h=r} (\vartheta_r - \vartheta_h) A_h + \sum_{h=s+1}^{h=n} (\vartheta_r - \vartheta_h + \vartheta^*) A_h}{q}$$

and, simplifying :

$$T_{a1}^{FD} = \vartheta_r + \frac{\vartheta^*}{q} \sum_{h=s+1}^{h=n} A_h - \vartheta_o^{**};$$

— for the second train :

$$T_{a2}^{FD} = \frac{\sum_{h=s+1}^{h=s} (\vartheta_s - \vartheta_h) A_h}{q} = \vartheta_s - \vartheta_o^{***}$$

in which  $\vartheta_o^{**}$  and  $\vartheta_o^{***}$  are the two barycentric times of arrival of service I when considering the respective departures of the first and second trains.

When we remember that the two trains both consist on departure of an equal number of wagons  $q$ , the total average waiting time is :

$$T_a^{FD} = \frac{T_{a1}^{FD} + T_{a2}^{FD}}{2}$$

$$\frac{1}{2} \vartheta_r + \frac{1}{2} \vartheta_s - \frac{1}{2} \frac{\vartheta^*}{q} \sum_{h=s+1}^{h=n} A_h - \vartheta_o^*$$

or again :

$$T_a^{FD} = \frac{1}{2} \vartheta_r + \frac{1}{2} \vartheta_s$$

$$- \frac{\vartheta^*}{Q_i} \sum_{h=1}^{h=r} A_h + \frac{1}{2} \vartheta^* - \vartheta_o^*. \quad (3)$$

We have to determine what values of  $\vartheta_r$  and  $\vartheta_s$  will make the value of the function (3) minimum.

Seeing that  $\vartheta^*$  and  $\vartheta_o^*$  are independent of  $\vartheta_r$  and  $\vartheta_s$ , we must give minimum values to :

$$f(\vartheta_r, \vartheta_s) = \frac{1}{2} \vartheta_r + \frac{1}{2} \vartheta_s - \frac{\vartheta^*}{Q_i} \sum_{h=1}^{h=r} A_h \quad (4)$$

For greater convenience, the second member of (4) should be multiplied by the constant  $\frac{Q_i}{\vartheta^*}$ . The function to be made minimum thus becomes :

$$f_1(\vartheta_r, \vartheta_s) = \frac{q}{\vartheta^*} \vartheta_r + \frac{q}{\vartheta^*} \vartheta_s - \sum_{h=1}^{h=r} A_h. \quad (4')$$

It should be pointed out that if we take  $\vartheta_r$  to be an independent variable,  $\vartheta_s$  becomes a function of  $\vartheta_r$ , since it is linked up with this latter by the relation :

$$\sum_{h=r+1}^{h=s} A_h = q$$

which makes it possible to determine, for every value of  $\vartheta_r$ , the corresponding value of  $\vartheta_s$ .

It is therefore advisable to write (4') in the form :

$$f_2(\vartheta_r) = \frac{q}{\vartheta^*} \vartheta_r + \frac{q}{\vartheta^*} F(\vartheta_r) - \sum_{h=1}^{h=r} A_h. \quad (4'')$$

in which  $F(\vartheta_r)$  is no other than the definite function which gives  $\vartheta_s$  as a function of  $\vartheta_r$  in virtue of the relation given above.

The problem of the minimum values can be solved easily by using a graphical method once again.

Let us put :

$$y_1 = \frac{q}{\vartheta^*} \vartheta_r; \quad y_2 = \frac{q}{\vartheta^*} F(\vartheta_r); \quad y_3 = \sum_{h=1}^{h=r} A_h$$

in which  $y_1, y_2, y_3$  are functions of  $\vartheta_r$  which can take the  $n$  values  $\vartheta_1, \vartheta_2, \dots, \vartheta_n$ .

Whereas the stepped diagram of  $y_3$  (see fig. 3) must take the value  $2q$  corresponding with  $\vartheta^*$ , the short straight line starting from the origin of the coordinates which represents the function of  $y_1$  must pass through the point of the coordinates  $(\vartheta^*, q)$ .

The diagram of the function  $y_2$  is on the contrary traced through points. The  $n$  values which  $\vartheta_r$  ( $\vartheta_1, \vartheta_2, \vartheta_3, \dots, \vartheta_n$ ), can have are considered, the  $n$  values of  $y_3$  [ $y_3(\vartheta_1); y_3$

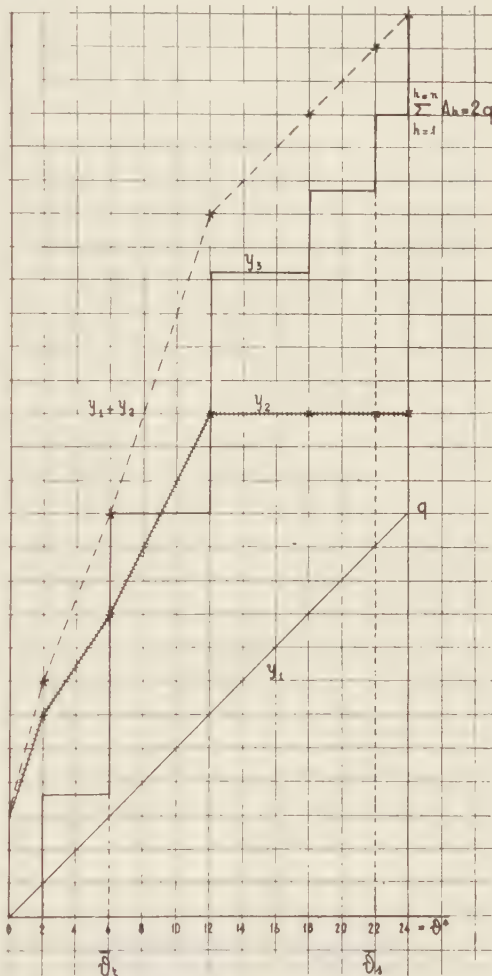


Fig. 3.

$(\vartheta_2), \dots, \vartheta_3 (\vartheta_n)]$ , are examined, the constant  $q$  is added and the  $n$  instants for which  $y$  has these values are determined. These instants represent the  $n$   $\vartheta_s$  we want. Multiplying each value of  $\vartheta_s$  by the ratio  $q/\vartheta^*$  we get  $n$  points on the graph for the function  $y_2$ . Two other points can be determined by considering the extremities 0 and  $\vartheta^*$  of the interval of variability of  $\vartheta_r$ .

The diagram of the function  $y_1 + y_2$  is easy to construct.

The function (4') will be minimum when  $\vartheta_r$  has the value corresponding to the minimum divergence :

$$\Delta_r = (y_1 + y_2) - y_3; \quad r = 1, 2, \dots, n.$$

Knowing  $\overline{\vartheta_r}$ , it is possible to determine the corresponding value of  $\overline{\vartheta_s}$ .

$\overline{\vartheta_r}$  and  $\overline{\vartheta_s}$  represent the times of arrival of the trains bringing the last lot respectively for the first and second trains leaving, so that the average waiting time  $T_a^{FD}$  is a minimum :

$$T_a^{FD\min} = \frac{1}{2} \overline{\vartheta_r} + \frac{1}{2} \overline{\vartheta_s} - \frac{\vartheta^*}{Q_i} \sum_{h=1}^{h=r} A_h + \frac{1}{2} \vartheta^* - \vartheta_o^*.$$

The two proper times to make up the two trains are :

$$\vartheta_{e1} = \overline{\vartheta_r} + T_a + S_1^*;$$

$$\vartheta_{e2} = \overline{\vartheta_s} + T_a + S_1^*.$$

### Third case :

In the most common case, we can have :

$$Q_i = \sum_{h=1}^{h=n} A_h \cong Kq,$$

in other words, the number of wagons for service I arriving during a period  $\vartheta^*$  is more or less equal to the composition of  $K$  trains,  $K$  being any complete number greater than 2.

By analogy with the previous cases, it can be shown that we get the relation :

$$T_a^{FD} = \frac{1}{K} \vartheta_r + \frac{1}{K} \vartheta_s + \frac{1}{K} \vartheta_t + \dots - \frac{\vartheta^*}{Q_i} \sum_{h=1}^{h=r} A_h + \frac{1}{K} \vartheta^* - \vartheta_o^*,$$

in which  $\vartheta_r, \vartheta_s, \vartheta_t \dots$  represent the arrival times of the last lots  $A_r, A_s, A_t \dots$  for completing the formation of the 1st, 2nd, 3rd ... trains leaving, which each have  $q$  wagons for service I. Taking  $\vartheta_r$  as the independent variable  $\vartheta_s, \vartheta_t \dots$  become a function of  $\vartheta_r$ , since they are linked up with this latter respectively through the relations :

$$\sum_{h=r+1}^{h=s} A_h = q; \quad \sum_{h=s+1}^{h=t} A_h = q \dots$$

which makes it possible to determine for each  $\vartheta_r$  the corresponding values of  $\vartheta_s, \vartheta_t \dots$

$\overline{\vartheta_r}, \overline{\vartheta_s}, \overline{\vartheta_t} \dots$  can be determined by using the graphical method already used in the case of  $K = 2$ . This makes it possible to calculate the minimum average time of waiting at FD and the proper times at which to make up the trains.

4. — The determination of  $\overline{\vartheta_r}, \overline{\vartheta_s}, \overline{\vartheta_t} \dots$  can also take place according to a more satisfactory method than that just described, if it is possible to establish, by means of statistical enquiries, a function  $\Theta = \Theta(\vartheta_r)$  representing the density or frequency of arrival of the wagons (number of wagons coming in during a given unit of time) which form part of the relation considered in the interval  $0 - \vartheta^*$ . This function can also be expressed in an analytical form (for example by a development in series). If, however, we still wish to make use of a graphical calculation, it is sufficient to represent it in the system of cartesian coordinates. To do this, it is sufficient to divide up the period  $\vartheta^* = 24$  hours into a certain number of equal periods (one hour for example), using as ordinates at the end of each such period the number of wagons for the service which

have arrived during the period in question (frequency of arrivals) and extending the enquiry to several successive periods  $\vartheta^*$  to make sure that the results will be as accurate as possible. The points thus obtained will determine the density diagram which can be obtained by a process of adjustment, making a continuous curve  $\Theta = \Theta(\vartheta_r)$  as regular as possible, pass close to the points. The higher the number of wagons for this service, the closer the graph representing the density will be to actuality. To obtain certain and sure results, it is however sufficient to know how to determine accurately the zones of concentration and their relative values.

If this function is introduced, the expression  $T_a^{FD}$  in the most usual case will become:

$$T_a^{FD} = \frac{1}{K} \vartheta_r + \frac{1}{K} \vartheta_s + \frac{1}{K} \vartheta_t - \dots - \frac{\vartheta^*}{Q_i} \int_0^{\vartheta_r} \Theta(\vartheta_r) d\vartheta_r + \frac{1}{K} \vartheta^* - \vartheta_o^*.$$

It is therefore necessary to make minimum:

$$f_k(\vartheta_r) = \frac{q}{\vartheta^*} \vartheta_r + \frac{q}{\vartheta^*} \vartheta_s + \frac{q}{\vartheta^*} \vartheta_t \dots - \int_0^{\vartheta_r} \Theta(\vartheta_r) d\vartheta_r,$$

in which  $\vartheta_s, \vartheta_t \dots$  are a function of  $\vartheta_r$ , since they are connected thereto respectively by the relations :

$$\int_{\vartheta_r}^{\vartheta_s} \Theta(\vartheta_r) d\vartheta_r = q; \quad \int_{\vartheta_r}^{\vartheta_t} \Theta(\vartheta_r) d\vartheta_r = q \dots$$

which make it possible to determine, for each  $\vartheta_r$ , the corresponding values of  $\vartheta_s, \vartheta_t \dots$

Let us apply this for  $K = 2$ . In this case we have :

$$f_2(\vartheta_r) = \frac{q}{\vartheta^*} \vartheta_r + \frac{q}{\vartheta^*} \vartheta_s - \int_0^{\vartheta_r} \Theta(\vartheta_r) d\vartheta_r.$$

Let us put as usual :

$$y_1 = \frac{q}{\vartheta^*} \vartheta_r; \quad y_2 = \frac{q}{\vartheta^*} \vartheta_s; \quad y_3 = \int_0^{\vartheta_r} \Theta(\vartheta_r) d\vartheta_r.$$

In the graph of figure 4, we have shown by a curve of periodic character the function  $\Theta = \Theta(\vartheta_r)$ , which represents the density of the incoming wagons, obtained by enquiries of a statistical nature. The curve of  $\Theta(\vartheta_r)$  indicates a very marked concentration at one particular point of the period  $\vartheta^*$ . In each period, the surface of the diagram must be equal to  $2q$ . Consequently :

$$\int_0^{\vartheta^*} \Theta(\vartheta_r) d\vartheta_r = 2q.$$

The function  $y_1$  is represented by the short straight line  $O I$ , which starts from the origin of the coordinates and has as its ordinate the value  $q$  corresponding to the abscissa  $\vartheta^*$ .

The function  $y_3$  is determined by integrating graphically the diagram of the function  $\Theta = \Theta(\vartheta_r)$ . The curve representing  $y_3$  must start from the origin of the coordinates and must have for the abscissa  $\vartheta^*$ , an ordinate of value  $2q$ .

The diagram of the function  $y_2$  is traced as usual through points. For a given point  $\vartheta_r$ , of the abscissae, the corresponding value of  $\vartheta_s$  of the function  $y_3$  is determined, the constant  $q$  is added, and in this way point B is obtained. A line is traced through B parallel to the axis of  $\vartheta$  up to the point where it meets  $y_3$  at point C. The abscissa of this point represents the looked for value of  $\vartheta_s$  satisfying the relation :

$$y_3(\vartheta_s) - y_3(\vartheta_r) = \int_{\vartheta_r}^{\vartheta_s} \Theta(\vartheta_r) d\vartheta_r = q.$$

In view of the fact that the function  $y_3$  increases with  $\vartheta_r$ , to each value of  $\vartheta$  there always corresponds a single value of  $\vartheta_s$ . By multiplying the value of  $\vartheta_r$  obtained in this way by the ratio  $q/\vartheta^*$ , the ordinate  $y_2$  corresponding to  $\vartheta_r$  is determined.



responding to  $\vartheta_r$  is found by the same method as any other value of  $\vartheta_s$ .

Making use of the well known system of graphic statistics, it is easy to determine the abscissa  $\vartheta_o^*$  of the centre of gravity of the diagram  $\Theta$  and then to calculate the minimum value of the average waiting time  $T_a^{FD}$  and the two moments  $\vartheta_e$  and  $\vartheta_{e2}$  most suitable for collecting the wagons.

It is hardly necessary to point out, it being self-evident, that the hatched diagram of figure 4, read from the scale  $Q_i/\vartheta^*$  represents, reduced by the constant  $1/2 \vartheta^*$  —  $\vartheta_o^*$ , the variation of the average time of waiting  $T_a^{FD}$  when  $\vartheta_r$  varies (hour of arrival of the last lot for the service in question intended to leave on the first train) from 0 to  $\vartheta^*$  or, at any rate when  $\vartheta_{e1}$  (hour at which the wagons intended for the first train to leave are collected) varies from 0 to  $\vartheta^*$ .

5. — Even if the density  $\Theta$  can sometimes be expressed by a very simple function of  $\vartheta_r$ , possibly by making use of a development in series, use should always be made of the graphic solution, the determination by analysis of  $\overline{\vartheta_r}$ ,  $\overline{\vartheta_s}$ ,  $\overline{\vartheta_t}$ , ...,  $\overline{\vartheta_o}$  and consequently of  $T_a^{FDmin}$ ;  $\vartheta_{e1}$ ,  $\vartheta_{e2}$ ,  $\vartheta_{e3}$  being in every case extremely complicated.

To support what we have just said, we will give a few examples.

- a) *Constant allocation with two trains leaving, each of composition q (for the graphical solution, see fig. 5) :*

$$\Theta(\vartheta_r) = C.$$

As we must have :

$$\int_0^{\vartheta^*} C d\vartheta_r = 2q; \quad \int_{\vartheta_r}^{\vartheta_s} C d\vartheta_r = q,$$

we get :

$$\Theta(\vartheta_r) = C = \frac{2q}{\vartheta^*}; \quad \vartheta_s = \frac{\vartheta^*}{2} + \vartheta_r,$$

and consequently :

$$\gamma_1 = \frac{q}{\vartheta^*} \vartheta_r; \\ \gamma_2 = \frac{q}{\vartheta^*} \left( \frac{\vartheta^*}{2} + \vartheta_r \right); \quad \gamma_3 = \frac{2q}{\vartheta^*} \vartheta_r,$$

whence :

$$\Delta_r = (\gamma_2 + \gamma_2) - \gamma_3 = \frac{q}{2}.$$

The divergence  $\Delta_r$  being constant, the average waiting time in FD will also be constant, whatever the moment at which collection takes place for the first train.

Consequently if we take any value of  $\overline{\vartheta_r}$  we get :

$$\overline{\vartheta_s} = \frac{\vartheta^*}{2} + \overline{\vartheta_r}.$$

Consequently, in view of the fact that in this case  $\vartheta_o^* = \frac{\vartheta^*}{2}$  :

$$T_a^{FD} = \frac{1}{2} \overline{\vartheta_r} + \frac{1}{2} \left( \frac{\vartheta^*}{2} + \overline{\vartheta_r} \right) \\ - \frac{\vartheta^*}{2q} \frac{2q}{\vartheta^*} \overline{\vartheta_r} + \frac{1}{2} \vartheta^* - \frac{1}{2} \vartheta^*,$$

and, simplifying :

$$T_a^{FDmin} = \frac{1}{4} \vartheta^* = 6 \text{ h (if } \vartheta^* = 24 \text{ h)}.$$

*Observation.*

In the case of K trains leaving, it is easy to show that :

$$\overline{\vartheta_s} = \frac{\vartheta^*}{K} + \overline{\vartheta_r}; \quad \overline{\vartheta_t} = \frac{\vartheta^*}{K} + \overline{\vartheta_s} \dots$$

and that :

$$T_a^{FD} = \frac{\vartheta^*}{2K}.$$

In other words, with a constant density of wagons arriving during the period  $\vartheta^* = 24$  hours, the K trains leaving must be

spaced at a constant time interval of  $\frac{\vartheta^*}{K} = \frac{24}{K}$  hours, which will make it possible to obtain, under these conditions, a waiting time in FD equal to  $\frac{\vartheta^*}{2K} = \frac{12}{K}$ .

The need to have equal time intervals between trains leaving only occurs in the case where there is a constant allocation of the number of wagons arriving, which as is known, hardly even occurs in practice.

As we should have :

$$\int_0^{\vartheta^*} C \vartheta_r d\vartheta_r = 2q; \quad \int_{\vartheta_r}^{\vartheta_s} C \vartheta_r d\vartheta_r = q,$$

we get :

$$\Theta(\vartheta_r) = C \vartheta_r = \frac{4q}{\vartheta^{*2}} \vartheta_r;$$

$$\vartheta_s = \sqrt{\frac{\vartheta^{*2}}{2} + \vartheta_r^2}$$

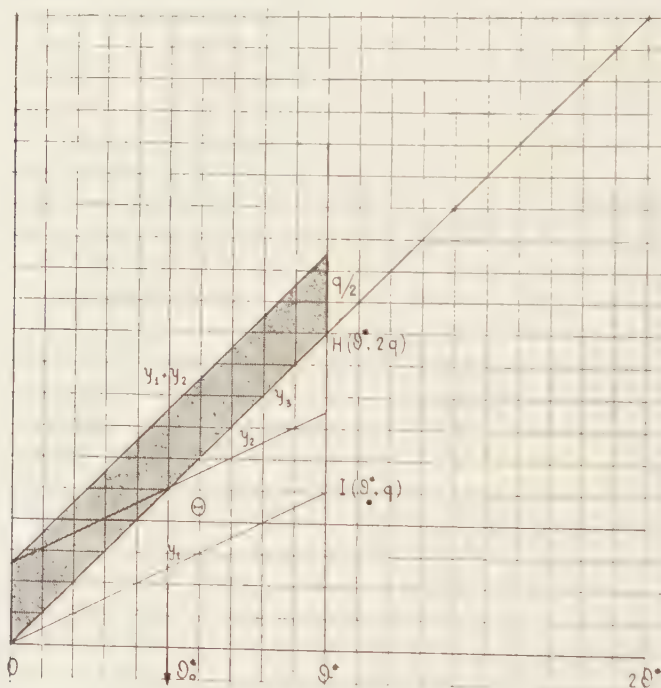


Fig. 5.

- b) *Triangular allocation, with two trains leaving, each of composition q (for the graphic solution see fig. 6) :*

and consequently :

$$y_1 = \frac{q}{\vartheta^*} \vartheta_r;$$

$$\Theta(\vartheta_r) = C \vartheta_r.$$

$$y_2 = \frac{q}{\vartheta^*} \sqrt{\frac{\vartheta^{*2}}{2} + \vartheta_r^2}; \quad y_3 = \frac{2q}{\vartheta^{*2}} \vartheta_r^2,$$

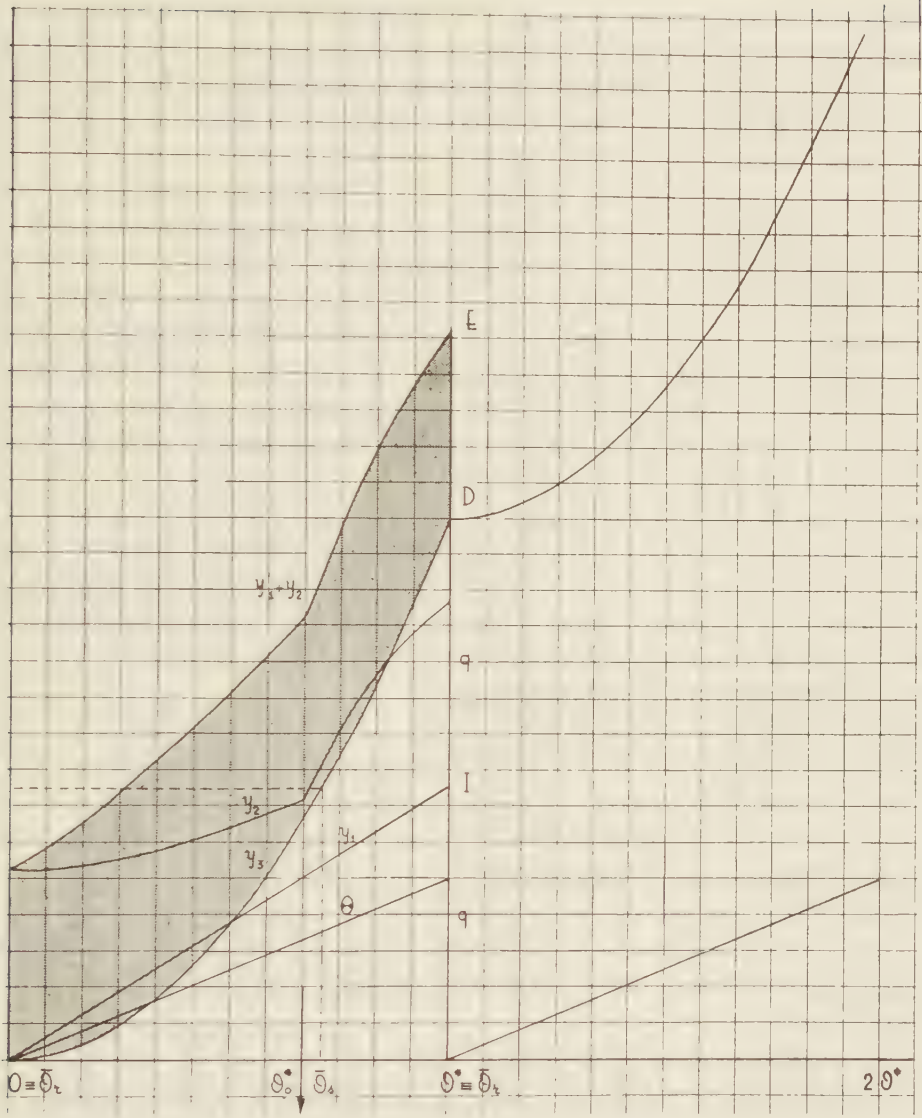


Fig. 6.

whence :

$$\Delta_r = (y_1 + y_2) - y_3$$
$$= \frac{q}{\vartheta^*} \left( \vartheta_r + \sqrt{\frac{\vartheta^{*2}}{2} + \vartheta_r^2} - \frac{2}{\vartheta^*} \vartheta_r^2 \right);$$

in derivation compared with  $\vartheta_r$  and making it equal to zero, we get :

$$\frac{d\Delta_r}{d\vartheta_r} = \frac{q}{\vartheta^*} \left( 1 + \frac{\vartheta_r}{\sqrt{\frac{\vartheta^{*2}}{2} + \vartheta_r^2}} - \frac{4}{\vartheta^*} \vartheta_r \right) = 0,$$

whence :

$$1 + \frac{\vartheta_r}{\sqrt{\frac{\vartheta^{*2}}{2} + \vartheta_r^2}} - \frac{4}{\vartheta^*} \vartheta_r = 0,$$

or else :

$$\frac{\vartheta_r}{\sqrt{\frac{\vartheta^{*2}}{2} + \vartheta_r^2}} = \frac{4}{\vartheta^*} \vartheta_r - 1.$$

By squaring we get :

$$\frac{\vartheta^{*2}}{\frac{\vartheta^{*2}}{2} + \vartheta_r^2} = \frac{16}{\vartheta^{*2}} \vartheta_r^2 - \frac{8}{\vartheta^*} \vartheta_r + 1,$$

or :

$$\vartheta_r^4 - \frac{1}{2} \vartheta^* \vartheta_r^3 + \frac{1}{2} \vartheta^{*2} \vartheta_r^2 - \frac{1}{4} \vartheta^{*3} \vartheta_r + \frac{1}{32} \vartheta^{*4} = 0.$$

The value of  $\overline{\vartheta_r}$  which should lie between 0 and  $\vartheta^*$  is obtained by solving an algebraic equation of the fourth degree.

But with the graphical solution (fig. 6) it is easy to see that :

$$\overline{\vartheta_r} = \vartheta^*$$

and consequently, owing to the periodicity of the phenomenon :

$$\overline{\vartheta_r} = 0.$$

Consequently :

$$\overline{\vartheta_s} = \sqrt{\frac{\vartheta^{*2}}{2} + \overline{\vartheta_r^2}} = \frac{\vartheta^*}{\sqrt{2}} \simeq \vartheta^*/1.41.$$

This solution could only be obtained from the analytical solution because the function:

$$\Delta_r = (y_1 + y_2) - y_3$$

shows, at the abscissae points 0 and  $\vartheta^*$  singular points at which the derivation is not cancelled out.

*Observation :*

In the case of K trains leaving, when  $\overline{\vartheta_r}$  has been determined we have :

$$\overline{\vartheta_s^2} = \frac{\vartheta^{*2}}{K} + \overline{\vartheta_r^2};$$

$$\overline{\vartheta_t^2} = \frac{\vartheta^{*2}}{K} + \overline{\vartheta_s^2} \dots$$

in other words, with a triangular density, the difference of the squares of the successive hours spread out of K trains leaving must

be constantly equal to  $\frac{\vartheta^{*2}}{K}$ . There is therefore no longer an equal time spacing allocation of trains leaving.

6. — If we remember that we designated by  $T_a^{\text{FP}}$  and  $S_2^*$  respectively the average waiting time before the operation of preparing to depart and the time of operation relating to the second phase, the theoretical hour of departure of the service I under the hypothesis  $Q_i \simeq q$  will be :

$$t_1 = \vartheta_{e1} + T_a^{\text{FP}} + S_2^*$$

and, if  $Q_i \simeq 2q$ , we will have :

$$t_1 = \vartheta_{e1} + T_a^{\text{FP}} + S_2^*;$$

$$t_2 = \vartheta_{e2} + T_a^{\text{FP}} + S_2^*$$

and so on.

To take lost time into account, which may have different values at each marshalling yard, it is necessary to put :

$$t_1 = \vartheta_{e1} + T_a^{\text{FP}} + \gamma S_2^*;$$

$$t_2 = \vartheta_{e2} + T_a^{\text{FP}} + \gamma S_2^*;$$

$$\dots \dots \dots$$

in which  $\gamma$  is the coefficient of correction to which we have already referred, which varies in practice between 1.2 and 1.8 and can be determined in each case.

The relations (6) make it possible to establish the spacing of the trains leaving a marshalling yard which will satisfy the

condition of minimum waiting time on FD, leaving it to an intelligent critical estimation to decide the suitable average waiting times in FA and FP as a function respectively of the quantity of wagons arriving and departing, and the number of staff employed.

The results obtained will also make it possible to determine the theoretical average sojourn of the wagons at a marshalling yard for each individual service.

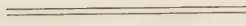
This is expressed by the formula :

$$S_m = T_a^{FA} + T_a^{FD} + T_a^{FP} + S_1^* + S_2^* . \tag{7}$$

We think it useful to draw attention, in the case of relations involving only one or

two departures every 24 hours, to the preponderance of the average waiting time on FD compared with those on FA and FP, and consequently to the need to assure that departures take place as a function of the effective allocation of arrivals, in order to have a satisfactory average time in the marshalling yard, as close as possible to the theoretical value given by the relation (7).

The practical application of the results obtained presupposes a knowledge of all the characteristic parameters of the marshalling yards (operating times and average waiting times) which we propose to deal with at greater length in a future article, giving the statistical-mathematical methods to be used to calculate these.



# The Tekken system rail gas pressure welding method,<sup>(\*)</sup>

by SHIN-ICHI AOYAMA.

(Bulletin of Permanent Way Society of Japan, Vol. 1, No. 9, December 1960.)

## 1. The Preface.

The Railway Technical Research Institute, JNR, completed a new rail gas pressure welding machine in 1957. In making standard rails (25 m) from short ones in a factory and long rails in the field, the results such as mentioned later in this report were obtained. It is worthy of special mention that so far no failure has occurred in any welded point.

(1) Manufacturing standard rails (25 m) from short ones in a factory :

The number of welding jobs  
About 70 000

(2) Preparing long rails in the field :

The number of welding jobs  
About 7 800

The total length of the track consisting of rails welded with this machine is approximately 120 km and the maximum length of a single welded rail is 1 475 m, laid between Fujisawa and Chigasaki on the Tokaido Line.

At present, there are seven Tekken type rail gas pressure welders including a trial-manufactured one.

Six sets are owned by the Japanese National Railways and one by the Nagoya Railway K.K. One unit is to be exported to the Nationalist China (Formosa) to be used by the Formosan Railway in 1961.

Furthermore, a bigger model of this machine is planned for construction to be used on the new Tokaido Main Line.

The Tekken type rail gas pressure welder is of an entirely unique design, in 1955 patents on the structure of main body and the burner were granted to the JNR.

Here a brief explanation is given of the structure of this machine, the welding operations in general using this apparatus, the results of such operations and the welding operations as well.

## 2. The apparatus for welding rails

The apparatus for welding rails comprise, in the case of factory work, the welder, rail bender, circular saw, two-rail drill, grinder for finishing, roller veyor and loading device or, in the case of field operations, the welder, centering machine, simple portal crane, grinder for finishing the end surfaces and the wheel sections, winch, rail bender, roller veyor, generator and tools for removing the rails.

Except the welder, the above-mentioned apparatus in factory work are similar to those in use in a rail flash butt welding plant, and in field work, except the welder and the centering machine, all are portable and easy to fix.

Here the welder is described with emphasis on the patented points.

The present rail gas pressure welding machine consists of a welding machine proper, gas pressure system, gas system, water-cooling system, measuring instruments, car and device and bed.

(\*) « Tekken » is the abbreviation for the « Tetsudo Gijutsu Kenkyusho » (Railway Technical Research Institute).

The rails to be welded are introduced by the rollers attached to both ends of the machine, made to thrust to each other, end to end, at the center of the machine clamped at their webs, and oil pressure is applied to the two oil pistons and while the prescribed pressure is being applied, the surfaces to be welded are heated by

3) The burner for heating (See Table 2).

4) The number of gas cylinders: 12 for oxygen and 12 for acetylene.

5) The protective water tank for cooling the burner and the body.

Diameter  $\times$  height  $\times$  capacity: about 590 mm  $\times$  3 300 mm  $\times$  900 l.

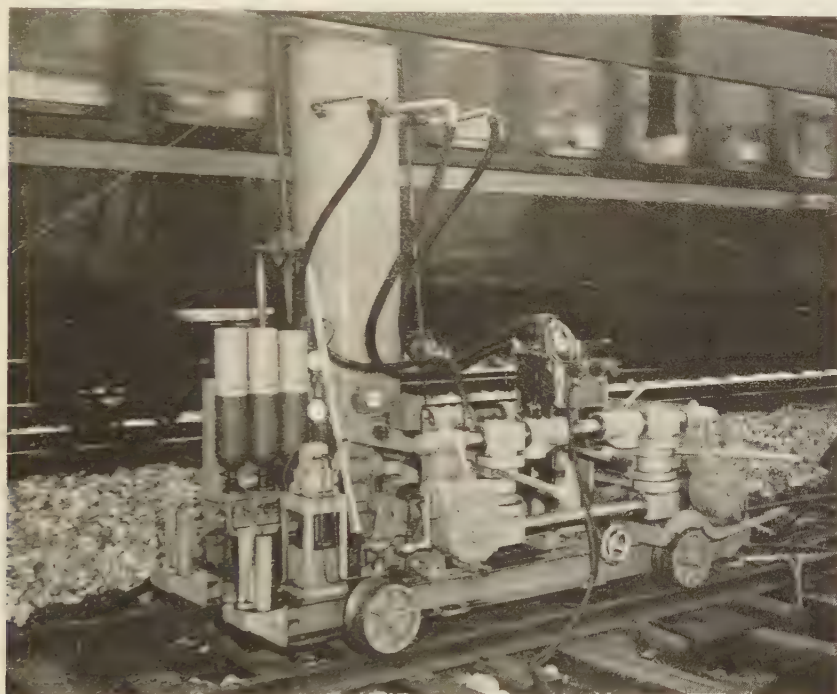


Fig. 1. — The « Tekken » type rail gas pressure welder.

an oxyacetylene burner and pressure-welded.

The external view of the welder is as shown in figure 1. Principal specifications of the welder are as follows:

1) Overall breadth 1 370 mm, overall length 3 030 mm, overall height 1 400 mm, and weight (not including the water tank and the gas system) 2.7 tons.

2) The upsetting forces and the oil pressures for types of rails to be welded are indicated in Table 1.

6) The running wheels. Diameter 250 mm, gauge 1 067 mm.

7) Wheels for lateral movement. Diameter 100 mm, gauge 2 680 mm.

#### *2-1. The mechanism for rail clamping and upsetting.*

As figure 2 shows, if one operates the forked arms by the lever which releases the grasping block, holds the webs of rails by the clamping shoes which move

TABLE 1. — Rail types, upsetting forces and oil pressures.

Rail types (kg/m)	Upsetting force (ton)	Oil pressure (kg/cm <sup>2</sup> )
50	19	150
37	14	110
30	11	85

TABLE 2. — Gas flux and consumption.

Type of rail (kg/m)		50	37	30
Flux (l/h)		9 900	7 300	6 100
Consumption l/job	Oxygen	1 100	770	560
	Acetylene	850	610	440
Mixed gas pressure		About 80 mm Hg		

only in parallel to each other, and while making the clamping shoes pressed tightly to the rail webs, makes the oil piston work in the pressurizing direction, the left

than the friction angle formed by the rails and the clamping shoes.

Because this upsetting force is balanced by the holding mechanism of the same

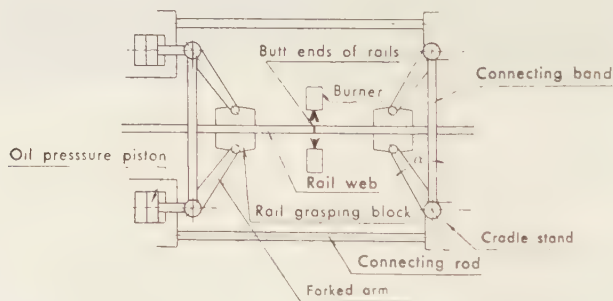


Fig. 2. — The mechanism of rail clamping and upsetting.

and right forked arms are pressed to the cradle, holding the rails, with a force proportionate to the welding pressure, without slipping because the angle  $\alpha$  is smaller

system on the cradle, the desired amount of upsetting force is engendered on the contacting surfaces of the rails.

The reactive force to the grasping force,

which arises in the forked arm, is absorbed by the connecting belt, and if the deformation is ignored, only a tensile stress works in the connecting rod in reaction to the upsetting force.

Furthermore, because the connecting rod and other members are arranged in a symmetrical position to the load, no deformation of the machine due to an unbalance of forces arises.

valves of the control valve, which has been pushed open by a cam. Thereby the oil on the return side is discharged into the oil tank.

Thus a welding pressure upon the rails is generated. Then, if one returns the control valve lever to the READY position, the two trap valves close.

If in that condition one operates the oil pump, the pressure oil enters the return

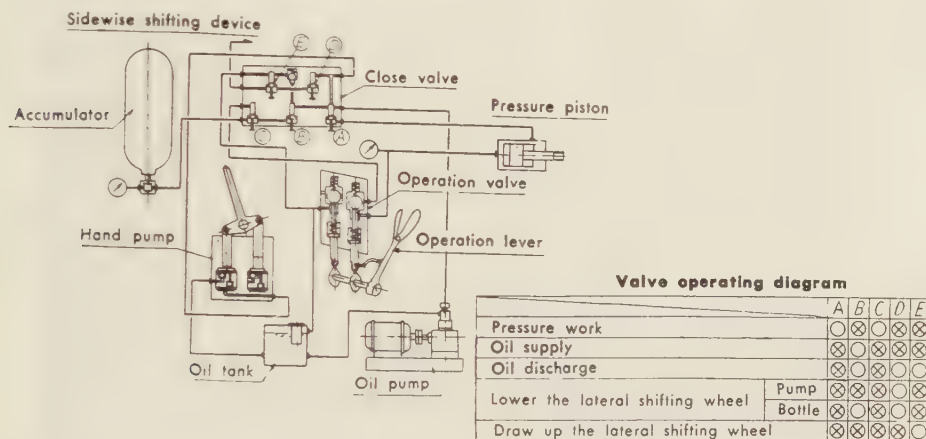


Fig. 3. — The oil pressure system.

Accordingly, no such force works as to bend the rails or to make their contact sections askew. Then, if one pushes back the oil piston, the forked arm rotates around the vertical pin, and the rails are freed from the clamping shoes.

## 2.2. The working of the oil pressure system.

It is explained how the oil pressure system works chiefly with regard to the welding operations. If, as shown in figure 3, one places the control valve lever in the READY position, closes valves B, D and E, and opens valves A and C, and after adjusting the oil pressure of the accumulator to the prescribed value, sets the control valve lever to the upset-welding position, the oil in the accumulator presses out the oil piston through the two trap

side of the oil cylinder, pushes back the piston and at the same time pushes back the oil in the pressurizing side into the accumulator and restores the oil amount as well as the oil pressure to the original state.

Accordingly, always the same pressurizing condition is maintained. Furthermore, by operating the valve as shown in the figure, one can refill the accumulator with oil, or discharge it and move vertically the wheel for lateral movements.

## 2.3. The gas system.

In order to decompress great amounts of oxygen and acetylene to about 80 mm on the mercurial columns and to adjust the fluxes to the prescribed amounts, oxygen and acetylene from 12 each gas pressure cylinders are decompressed in two

steps by large reducing valves and pressure equalizers and supplied to the burners.

As safety devices, a dry type safety valve and an explosion preventive are provided. The flame scarfing burner (\*) is supplied with oxygen and acetylene respectively via the front and the rear of the pressure equalizers.

#### 2.4. The burner for heating.

As figure 5 shows, the burner is in symmetrical position to the section of the rails. It consists of an all-round conti-

A mercury pressure gauge is attached to the gas chamber and measures the pressure of the gas which is emitted.

The cooling of the burner is automatically done by natural circulation which occurs due to thermo-syphon effect.

### 3. The welding operations.

Whether indoors or outdoors, welding operations consist of the following five steps:

1) The preparation of the rails to be welded; 2) upset welding operations pro-

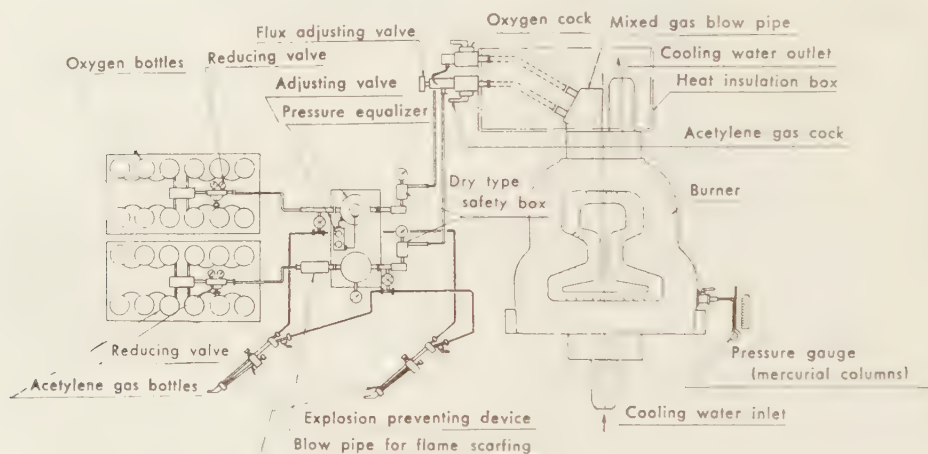


Fig. 4. — The gas system.

nuous gas chamber and cooling water chambers which sandwich the gas chamber and is made of one block cast aluminum alloy. It has been anode-treated and MA-fluid treated to have an anti-corrosive and anti-pressure nature.

The gas enters from the metering orifice fixed above and ejects out of the numerous brass nozzles arranged in series on the inner side of the gas chamber and heats the entire circumference of the rails evenly.

(\*) The flame scarfing is an operation to burn off the excess metal from the welded part and to even out the surface.

per; 3) finishing the rails with a grinder; 4) a non-destructive test; and 5) the rectification of the welded rail and a lateral and vertical deformation checkup.

Outdoor operations are not conducted when it rains or when it is windy.

Each step is briefly explained in the following paragraphs.

#### 3.1. The preparation of rails.

1) The rails are carefully rectified beforehand so that the finish may be fine. 2) When used rails are to be welded, two rails with the same degree of wear ought

to be selected, their battered ends are cut off with a circular saw, and the oil on the end surfaces is carefully washed off with caustic soda solution or the like; 3) If new rails are to be welded, the rust and paint, if any, have to be removed from the end surfaces with a grinder; 4) because the degree of the end surface finish greatly

process of pressuring and heating, the prescribed compression has been obtained, put out the fire, and after compressing by another 4 mm, remove the upsetting pressure; 5) immediately remove either the rails or the welding machine, bring out the rails, and remove the excess metal at the welded part by the flame-scarfing process while it



Fig. 5. — The burner for heating.

affects the welding effect, the end surfaces must be finished as cleanly and as evenly as possible and must be accurately at right angles with the axial direction of the rails.

### 3-2. *Welding operations.*

1) Induct the rails into the welder, wipe the surfaces to be welded with clean cloth or carbon tetrachloride; 2) grasp the rails at their webs with the clamping shoes, set them center to center and apply upsetting pressure; 3) heat the welding part with the burner up to a temperature between 1 150° C and 1 200° C; 4) when, in the

is still red-hot; 6) return the rail or the welder to the original position, and anneal the rail for about 1'30" with the burner used for heating. The temperature in annealing is between 800° C and 900° C; 7) after the annealing, leave the rail to be air-cooled. The heating time and the amount of upsetting are shown in Table 3.

### 3-3. *Finish by a grinder.*

1) Applying the 400 mm straight-edge and a surface plate painted with minium, finish the upper and lateral surfaces of the welded rails with a grinder and a file

TABLE 3. — Heating time and the amount of upsetting.

Type of rail (kg/m)	Heating time	Upset while heating	Upset after quenching	Total Upset
50	3'15" — 4'45"	18 mm	4 mm	22 mm
37	2'40" — 3'10"	16 mm	4 mm	22 mm
30	2'35" — 3'00"	16 mm	4 mm	22 mm

until no gap remains; 2) the entire under-surface of the base and such part of the upper surface of the ends of the base as lies within 20 mm from each edge must be roughly finished with a grinder until the 400 mm straight-edge touches uniformly; 3) the web must be cleared of the excess metal by flame-scarfing but need not be finished.

#### 3-4. *Non-destructive tests.*

Numerous strength tests conducted in the past revealed weak points such as non-welded section only at both ends of the base. If there is such a defect, the strength of the rail greatly decreases.

Accordingly, one must conduct a non-destructive test by the paint penetrant method and check the ends of the base, and if one detects a defect, one must cut the rail and weld it again.

This procedure greatly increases the reliability of the products. Paints used for the non-destructive tests include dye-mark and red check.

#### 3-5. *The rectification of the product and the lateral and vertical checkup.*

1) Welded rails may be rectified while they are hot or cold as in the case of rectification of ordinary rails. In the lateral and vertical deformation test, one stretches a yarn for a 2-m span, pulls it with a 2 kg spring balance, and if the deviation of the center is within  $\pm 1$  mm, the lateral and vertical linearity is regarded passable.

### 4. The results of the strength test.

#### 4-1. *The standard strength.*

The standard strength of test pieces, according to criteria established by the Railway Technical Research Institute following a great many tests, is as shown below, regardless of the types of rails. However, the test rail should be a JIS rail with little segregation.

1) The joint efficiency in a bending test (both normal and inverse):  $95 \pm 3$  %, range: 77.5 % to 105 %.

The term « joint efficiency » here means the percentage of the strength of the welded portion to the strength of the base-metal rail and serves as a measure for judging the propriety of a welding method which uses no welding rod, such as flash butt welding.

2) As a result of a test upon a JIS test piece and of a rolling load test (the fatigue test of a full-size rail), it has been known that the strength of the welded section is equal to or greater than the strength of the original rail.

3) The hardness of the welded part is approximately the same as the hardness of the material rail although the distribution of the hardness was uneven, namely, there was a place about 15 mm in breadth and 60 mm distant forward and backward from the welded part where the hardness decreased by between 20 and 40 in terms of Brinell numbers.

TABLE 4. — Annealing effects.

	Standard operation	Without annealing
Average joint efficiency . . . . .	92.7%	77.7%
Range . . . . .	> 80%	> 62%
In excess of 100% . . . . .	7 units	2 units
Number of test pieces . . . . .	20	15

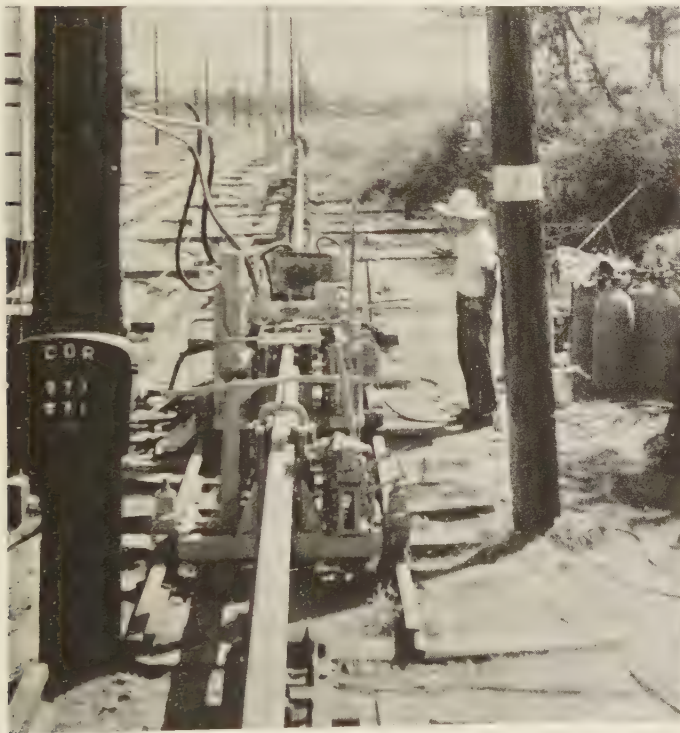


Fig. 6. — The field operations (between Fujisawa and Chigasaki, Tokaido Line).

#### 4.2. The test of the annealing effect.

By using 50 kg rails, we have compared a rail which has been annealed and a rail which has not been annealed and ascertained that the annealing is effective, as Table 4 shows.

#### 4.3. A test upon a rail having much segregation.

We pressure-welded rails with much segregation and conducted a bending test upon them. As a result, we have ascertained that the joint efficiency is bad (about

TABLE 5. — The numbers of welding jobs per unit of supplies.

Name		Unit	50 kg/m rail	37 kg/m rail
Oxygen cylinder (containing 6 000 l, residual pressure : 8 kg/cm <sup>2</sup> ) . . . . .		1	4	4.5
Acetylene cylinder (containing 7 kg, residual pressure : 3 kg/cm <sup>2</sup> ) . . . . .		1	4	4.5
Grindstone 175∅ × 45 B . . . . .		1	8	10
Grindstone 175∅ × 25 B . . . . .		1	8	10
File (rough pitch, 14") . . . . .		1	8	10
Carbon tetrachloride bottle (containing 500 g)		1	20	20
Bandage (quarter size 4.5 m in length) . . . . .		1	8	8
Dyemark	Detergent (500 g) . . . . .	1 bottle	36	36
	Penetrant (500 g) . . . . .	1 bottle	125	125
	Developer (500 g) . . . . .	1 bottle	63	63
Machine oil (No. 120) . . . . .		1 l	50	50
Minium . . . . .		1 g	1.6	1.6
Rag . . . . .		1 kg	32	32

N. B. — Fuel for generator and winch is not included.

TABLE 6. — The composition of the operation personnel.

Type of work	Technicians	Workers
Welding end surface finishing . . . . .	1	0
Rail delivery and removal . . . . .	0	3 — 4
Rail centering . . . . .	0	1
Operation of the welder . . . . .	2	0
Rail induction . . . . .	0	1
Operation of the winch . . . . .		2
Finishing the welded part by the grinder and inspection . . . . .	4	0
Superintendence . . . . .	1	0
Total . . . . .	8	7 — 8

80 % on the average) in such rails although the non-destructive test has revealed no particular abnormal signs on the broken section. Accordingly, it can be said that rails with much segregation are unfit to be welded.

#### 4.4. The gap test.

A gap of about 1 mm in thickness and about 20 mm in breadth was given to the

rail base, the rails were welded together and a bending test was conducted. As a result, a non-welded section remained at the end of the base, and the strength of the welded rail was very poor (the joint efficiency was below 60 %). However, when the gap was given to a different place of the rail, the strength was little affected.

TABLE 7. — The operation schedule.

	Preparation	Welding operation	Removal	Holiday
Days	3 days	14 jobs a day	2 days	one day per week

#### 4-5. The end surface staining test.

The end surfaces were made to rust or painted with oil and were welded. In some cases, the strength deteriorated greatly (the joint efficiency was below 60 %). In other cases, where there was much rust, the welded part fell apart during cooling.

#### 5. The field welding operations.

With reference to figure 6, figure 7 and Tables 5 to 7, a brief explanation of field welding operations with the Tekken type rail gas pressure welder is made as follows:

The cost of supplies per job of welding is about 1 000 yen in the case of a 50 kg rail.

#### 5-3. The operation personnel.

The composition of the operation personnel is shown in Table 6. Only such persons, however, as have passed the examination for operator's licence are qualified to operate the welding machine in preparing JNR rails. The personnel shown in Table 6 seems to have room for curtailment.

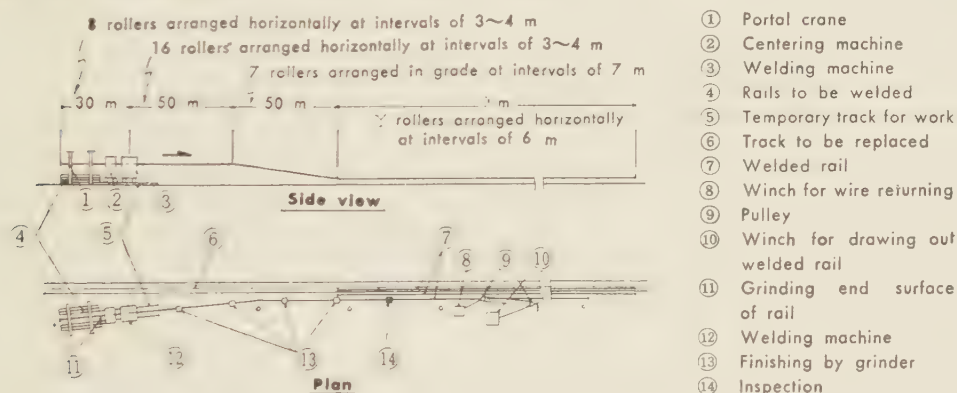


Fig. 7. — The arrangement of the welding apparatus.

#### 5-1. The arrangement.

The basic arrangements for field welding operations and the actual work are shown respectively in figures 6 and 7. In some cases of new track construction work, rails of the prescribed length are welded from one end of the track, the welder is carried further, then the welding is conducted again, and thus the track is gradually extended.

#### 5-2. Welding supplies.

The numbers of welding job per unit of welding supplies are shown in Table 5.

#### 5-4. The operation schedule.

Experiences teach that an operation schedule such as shown in Table 7 is recommendable. For skilled and experienced operators, however, it is possible to carry out more than 30 jobs per diem of welding in eight hour's shift.

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# Recent developments in tunnel permanent way techniques,

by Hans Ludwig HÄRTER, Dipl. Ing., Wuppertal.

(Eisenbahntechnische Rundschau, No. 8, August 1960.)

*The technical perfection of modern railway permanent way has also been extended to the improvement of railway tracks in tunnels. A number of methods, described below, will ensure a longer service life of the rails and more economic maintenance of permanent way in narrow tunnels where maintenance work is difficult.*

## 1. Extent and special features of tunnel tracks.

The 522 tunnels on the railway lines at present in operation in the territory of the German Federal Republic contain some 350 km of track, corresponding to an average of 8 km of tunnel track per 1 000 km of main line track of the German Federal Railway. Though the total length of tunnel track is thus relatively small, it is very unevenly distributed over the different railway regions. Thus, the proportion rises to nearly 30 out of 1 000 km in some regions such as Karlsruhe or Wuppertal; in others, such as Augsburg, Hamburg, Munich or Münster, it is virtually zero. Even between one line and another, the tunnel percentage may vary considerably; on the Offenburg-Villingen line in the Black Forest, for instance, it amounts to as much as 15 %. Since, in addition, such lines with many tunnels usually also have unfavourable curvatures and gradients, track maintenance becomes very expensive, as the special conditions applying to permanent way in tunnel always give rise to greater concern for the maintenance of tunnel track than for that of open track.

In particular, the high rate of corrosion experienced in long and badly ventilated tunnels gives rise to premature wear of rails and track fastenings. Such corrosion is due to the moisture which, even with the best possible sealing of the tunnel vault

and with most careful drainage arrangements, can hardly be kept away from the track completely. The corrosive effect is even greater if the water itself is highly corrosive. But even the air humidity alone, in conjunction with the sulphurous acid emanating from the smoke gases of the steam locomotives, is apt, to cause heavy corrosion of the rail metal.

In long tunnels, the wear of the rail head increases with the distance from the tunnel mouth and is generally twice as great, and in individual cases up to five times as great, as on open lines. Moreover, the intensified wear causes the premature loss of the force locking capacity of the fastenings.

## 2. Developments in tunnel permanent way techniques.

In these circumstances, it is not surprising that the permanent way in tunnels has always called for special efforts and increased attention on the part of the railway engineers. Moreover, since renewal and maintenance works in tunnels are not only difficult and dangerous but also extremely costly, one has always endeavoured to reduce the cost of such maintenance.

In spite of the relatively great quantity of metal fastenings, the « K » type standard permanent way which was introduced by the German Reichsbahn on open sections

in 1926 and is still regarded as satisfactory, has also, in the course of the years, been used increasingly in tunnels. For this purpose the beechwood sleeper has been found to be best suited. Steel sleepers have been avoided because of their own corrosion proneness, whilst oakwood sleepers have

the service life in tunnels by using a type of permanent way similar to that used for bull-headed rails in Britain, which was first used in Baden about fifty years ago and which, since 1928, has also been used elsewhere in Germany (fig. 1). This type of permanent way had the advantage that,

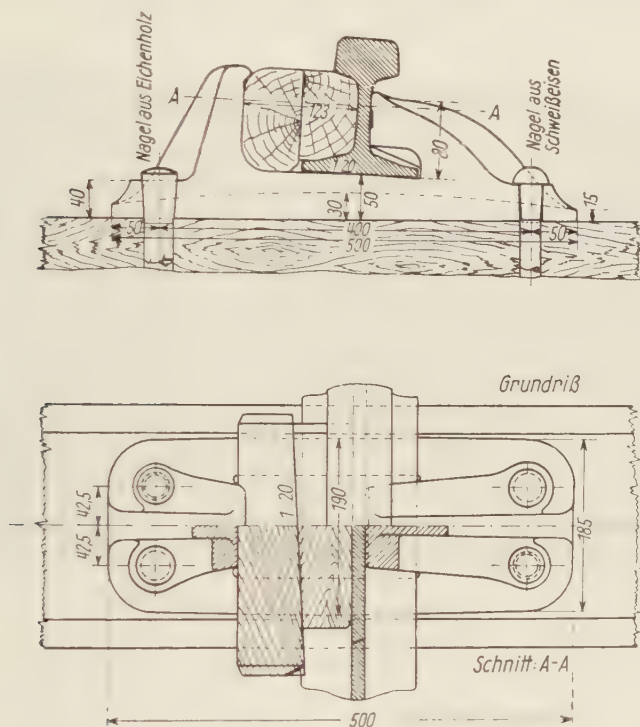


Fig. 1. — « T » type permanent way for tunnels.

The rail is fastened by means of hardwood wedges.

N. B. — Nagel aus Eichenholz = oakwood spike. — Nagel aus Schweisseisen = wrought iron spike. — Grundriss = plan. — Schnitt = section.

been avoided because the tannic acid contained in this wood favours the corrosion of the metal fastenings. Because of the relatively large total surface of the metal fastenings, their service life in tunnels is generally no longer than one-half or one-third, and in certain cases no more than about one-seventh, of that on open sections. The attempt was made to prolong

for the fastening of the rails to the cast iron chairs, no metal fastenings were needed. But it had the drawback that the wooden wedges tended to become loose very easily so that the tensioning of the track deteriorated. Since, moreover, this type of permanent way calls for a considerable quantity of materials and for heavy expenditure, it was abandoned in

1937 in favour of the « K » type permanent way.

In recent years, further noteworthy successes in reducing the cost of tunnel track renewal and maintenance have been achieved, mainly through structural measures. Among them are the elimination of the rail joints through continuous welding of the

welded to form lengths of 60, 90 or 120 m <sup>(1)</sup>. In 1930, continuous welding was applied, for the first time, to the whole length of a tunnel track in the 2 652 m long Rudersdorf Tunnel of the Ruhr-Sieg line. Although, in long tunnels, the temperature fluctuations are smaller so that the stresses are lower and the risk of rail

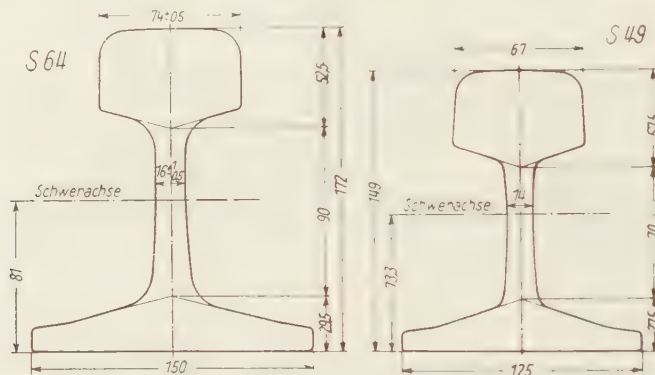


Fig. 2. — Cross-sections of rails S 49 and S 64.

N. B. — Schwerachse = centre line of rail.

Rails	Weight (kg/m)	Moment of inertia $J_x(\text{cm}^4)$	Section modulus $W_x(\text{cm}^3)$	Stability (width/height ratio)	Ratio of head and base areas
S 64	64.7	3260	358	0.87	1.131
S 49	49.4	1819	240	0.84	1.36

tunnel tracks; the use of rails of larger cross-section; the replacement of normal metal fastenings by elastic spikes; the use of sleeper-less permanent way on a solid base; the improvement of the wear resistance and corrosion protection of the rails, and finally, the improvement of working conditions in the tunnels.

#### a) Continuously welded tunnel rails.

In 1924, for the first time, tunnel rails of the then standard length of 15 m were

buckling is reduced, it was only with considerable hesitation that, in the following years, the policy of eliminating the rail joint — the weakest point in the track at large — was pursued further. For obvious reasons, nothing much could be done during the second world war and the immediate post-war years. By 1950, welding was

<sup>(1)</sup> BIRMANN : « Geschweisste Schienen in Tunneln » (Welded rails in tunnels). « Eisenbahntechnik », 1950, No. 1.

therefore still confined to not much more than 10 % of all tunnel tracks, with about one-third of them continuously welded. Since that time, however, continuous welding of rails in tunnels has been resorted to systematically. Since 1958, the introduction of the rapid welding method has made it possible to carry out rail welding operations even during relatively short inter-

same, the larger size and 1.5 times greater section modulus of this rail entails a considerably prolonged service life. Admittedly, the permissible vertical wear of S 64 rails in Class I track is not much greater than that permitted for the latest 149 mm high type of rail S 49 (16 mm, compared with 13 mm). In the case of rail S 49, however, even a vertical wear of no more than

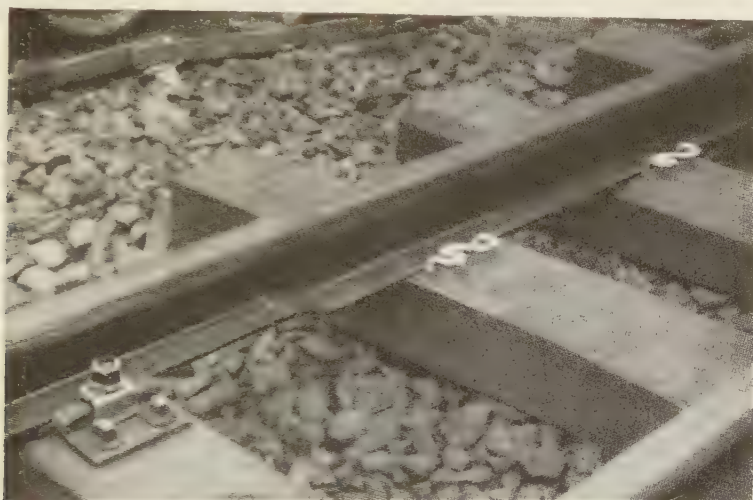


Fig. 3. — Track renewal with S 64 rail and twin elastic spike Dna 1; transition between permanent way types Hf 64 and K 49.

vals between trains. As a result there has been a drastic decrease in the number of rail fractures which in over 60 % of all cases on open sections and in an even higher percentage of all cases in tunnels, used to emanate from the fishing surfaces at the joints; moreover, the elimination of the need for maintaining the rail joints has given rise to considerable savings.

b) *Type « S 64 » rail.*

In 1952, the wear-resistant rail S 64 was introduced for use in long tunnels. With this rail, the width of the head is about one-tenth greater than that of rail S 49 (fig. 2), and although the rate of vertical wear, under equal conditions, is about the

9 mm, often in conjunction with the reduction in the section modulus caused by corrosion on all the surfaces of the rail, is apt to cause such a high fracture proneness that the height of the rail should, if possible, not be allowed to decrease below 140 mm. Rail S 64 can therefore be reckoned to have twice the service life of rail S 49.

c) *Elastic spikes.*

In order to reduce the quantity of metal fastenings, rail S 64 (which has a foot width of 150 mm) is directly fastened to the hardwood sleepers by means of elastic spikes, without sole plates, albeit with shim plates. With this « Hf 64 » type of permanent

way, the quantity of metal fastenings is reduced to about 2 kg per fastening point, compared with nearly 12 kg for « K 49 » type permanent way. In this connection,

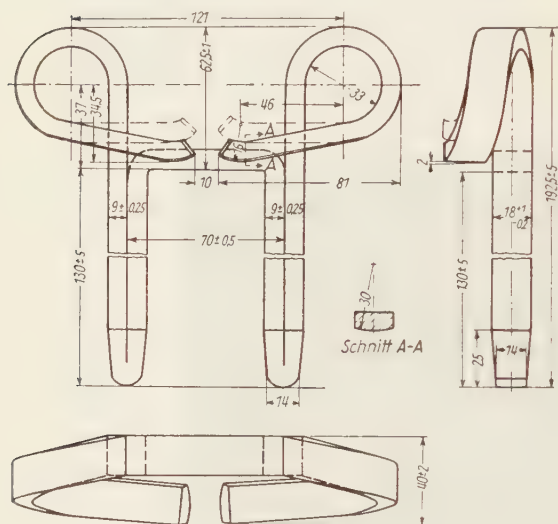


Fig. 4. — Twin elastic spike Dna 4.

N. B. — Schnitt = section.

elastic spikes with round cross-section, Dna 1 and Dna 2 (fig. 3), have not been found so satisfactory since they are liable, even on straight track, to become notched at the shaft and by the side of the rail foot in the course of time so that fatigue fractures are apt to occur. Occasionally, wear has even been observed on the loop lying on the rail foot. In curves with radii below 1 000 m, gauge widenings have been observed which were at least partly due to the notches. For this reason, « S 64 » rails lying in sharply curved tunnel sections have occasionally been laid on ribbed sole plates with gauge widening, designed for K 49; these « Rpm plates », which were taken from old stocks, were re-milled at the sides of the ribs to obtain a better seat for the clips. With elastic spikes of square cross-section, wear of this type was not experienced to the same extent, especially as these spikes have surface contact.

Apart from the prolonged service life of « Hf 64 » permanent way, reflected in reduced cost of renewal, the maintenance cost too will be considerably reduced since levels and alignment are altogether better preserved than with « K 49 » permanent

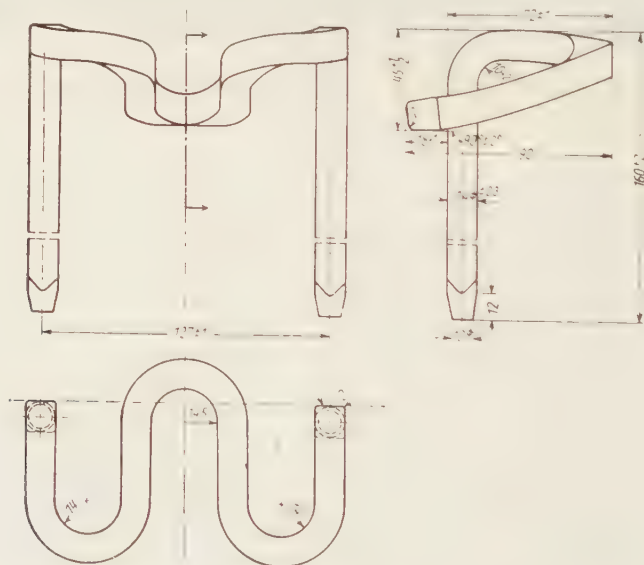


Fig. 5. — Twin elastic spike Dna 6.

way. But these features can only be quantified after a further trial period.

According to an instruction issued by the German Federal Railway in 1959, the standard permanent way of the line should be carried through tunnels of up to about 120 m length which experience has shown to be free from corrosion. In tunnels of a length exceeding 120 m, « Hf 64 » type permanent way should be used; where the corrosion risk is not great, twin elastic

permanent way in the tunnels have resulted in a considerable prolongation of the service life of the rails, and in an important reduction in the quantity of metal fastenings used. So far, however, it has not been possible to achieve any important improvement in the life of the sleepers, and especially in their gauge keeping capacity. Even for this reason, it seemed desirable to carry out trials with sleeper-less permanent way. According to specifications issued in 1957,



Fig. 6. — Hf 64 type permanent way with twin elastic spike Dna 6.

spikes Dna 4 (formerly known as double shaft elastic spikes) with a rectangular cross-section of  $9 \times 18$  mm (fig. 4) should be used; in all other cases, twin elastic spikes Dna 6 (formerly known as elastic rail clips) with a square cross-section of  $14 \times 14$  mm must be employed (fig. 5 and 6). The Omega-shaped twin elastic spike Dna 6 is geometrically similar to twin elastic spikes Dna 1 and Dna 2, the only difference being the cross-section of the spikes.

d) *A trial with sleeper-less permanent way.*

The continuous welding of the rails and the introduction of « Hf 64 » type per-

manent way in the tunnels have resulted in a considerable prolongation of the service life of the rails, and in an important reduction in the quantity of metal fastenings used. So far, however, it has not been possible to achieve any important improvement in the life of the sleepers, and especially in their gauge keeping capacity. Even for this reason, it seemed desirable to carry out trials with sleeper-less permanent way. According to specifications issued in 1957,

it was intended to find out whether it would be possible, in suitable cases, to lay the rails in a tunnel in such a way that, apart from minor adjustments in levels by means of shim plates placed under the rails, no subsequent adjustments would be required. Best suited for such trials were double-track tunnels without concrete invert, driven through solid rock and flanked by good tunnel walls, where track or sleeper renewal work was imminent in any case.

The trial specifications worked out by the German Federal Railway's Central Development Office at Minden, Westphalia, provided for the cross-sections shown in

fig. 7 and 8 <sup>(2)</sup>. According to these specifications, the cleaned tunnel invert is to be covered with a loadbearing layer of colcreted ballast. This layer is separated from the about 12 cm thick, steel mesh reinforced concrete slab by an insulating layer of approx. 5 cm thickness (fig. 7). Depending on local circumstances, the reinforced concrete slab may also be placed directly on the previously levelled rock bottom (fig. 8).

The track slab consists of in-situ cast concrete and contains, under each line of rails, recesses arranged at normal sleeper intervals in which precast concrete blocks can be inserted. On these blocks, the running rails must then be fastened by means of twin elastic spikes, with the insertion of poplarwood or rubber shim plates, using corrugated dowels. The blocks are embedded in concrete when the rails have been finally adjusted.

In 1959, this sleeper-less type of permanent way was built, by way of trial, in a 130 m long section of the Schönstein Tunnel on the Sieg line between Giessen and Cologne, and in the 233 m long Hengstenberg Tunnel of the line from Hagen to Brügge (fig. 9). The cost of construction was not inconsiderably higher than that of Hf 64 type permanent way. But this type of permanent way may well be economic in the long run since the need for sleeper and ballast renewals is completely eliminated and other rehabilitation work can remain confined to minor adjustments of levels. The sleeper-less track may be of special advantage where the track must be lowered in order to obtain the enlarged clearance gauge required for electric traction. As the structural height of the permanent way is reduced by the height of the sleepers, the sleeper-less track might even reduce or wholly obviate the need for lowering the tunnel invert. The headquarters administration of the German Federal Railway has therefore recommended the use of sleeper-less track in all cases where the track must be lowered. Ad-

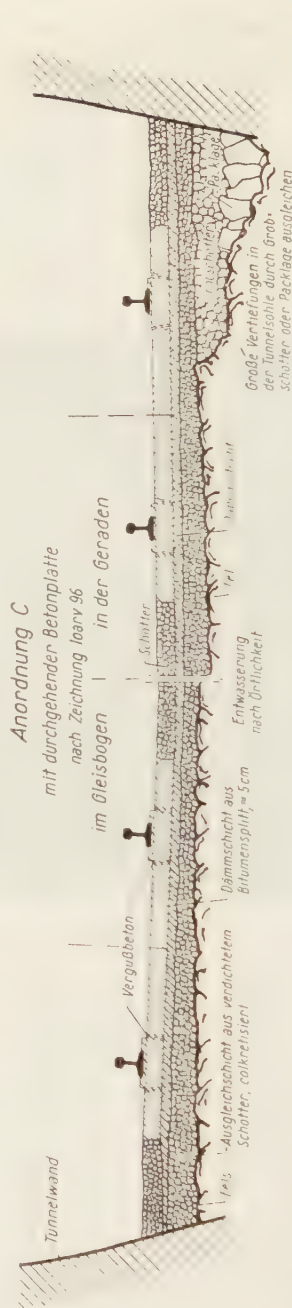


Fig. 7. — Sleeper-less permanent way for tunnels with rail S 64 as specified in Drawing Ioarv 79 a, Sheet 2.

Explanation of German wording :

Anordnung C... Ioarv 96 = arrangement C with continuous concrete slab in accordance with Drawing Ioarv 96. — Im Gleisbogen — in curved track. — In der Geraden — in straight track. — Tunnelwand — tunnel wall. — Vergussbeton — pouring concrete. — Schotter — ballast. — Fels — rock. — Ausgleichsschicht aus verdichtetem Schotter, colkretisiert — leveling course consisting of compact and colcreted ballast. — Dämmschicht aus Bitumensplitt — insulating layer consisting of approx. 5 cm thick bitumen coated chippings. — Entwässerung nach örtlichkeit — drainage, depending on local conditions. — Grobschotter — coarse crushed stone. — Packlage — stone pitching. — Grosse Vertiefungen — major cavities in the tunnel bottom must be leveled out by coarse crushed stone or stone pitching.

<sup>(2)</sup> Drawings Ioarv 79 a, Sheet 2, and Ioarv 96.

mittedly, however, it will then no longer be possible subsequently to increase the distance between parallel tracks which, in most tunnels, is no greater than 3.5 m.

It is still too early to make any statements about the success of the sleeper-less track as such, or about the transmission of track vibrations to the tunnel structure.

duced as a wear-resistant rail with a minimum strength of 90 kg/mm<sup>2</sup>. In sharp curves, wear can be reduced, apart from the lubrication of the wheel flanges of the vehicles, by stationary lubricating devices on the rails. Among anticorrosion measures which are apt to make a not inconsiderable contribution to the prolongation of the

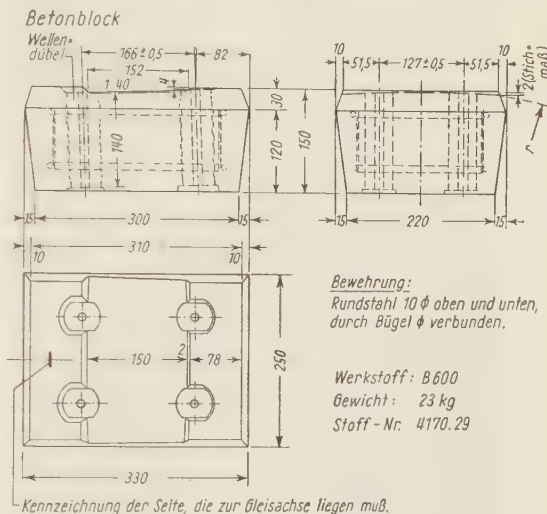
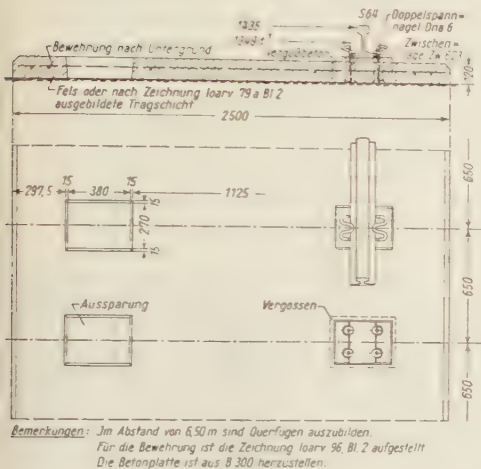


Fig. 8. — Sleeper-less permanent way for tunnels with rail S 64 as specified in Drawing Ioarv 96. Concrete block shown four times enlarged.

Explanation of German wording :

Ausparung = recess. — Vergossen = sealed. — Vergussbeton = sealing concrete. — Zwischenlage = shim plate. — Doppelspannangel = twin elastic spike. — Bewehrung nach Untergrund = reinforcement depending on sub-base. — Fels oder... = bedrock, or bearing layer provided as specified in Drawing Ioarv 79 a, Sheet 2. — Im Abstand von 6.50 m = transverse joints to be provided at intervals of 6.50 m. — Für die Bewehrung... = for steel reinforcement, see Drawing Ioarv 96, Sheet 2. — Die Betonplatte ist aus... = the concrete slab must consist of B 300. — Betonblock = concrete block. — Wellendübel = corrugated dowel. — Kennzeichnung... = marking the side facing the centre line of the track. — Rundstahl... = reinforcement: round irons 10 mm dia. top and bottom, connected by stirrups. — Werkstoff = material. — Gewicht = weight. — Stoff = Code No. 4170.29.

e) Improving the wear resistance and corrosion protection.

The metallurgical measures that can be taken to improve the wear and corrosion resistance of rail steel are limited by technical and, especially, economic considerations. An alloying admixture of 0.2 to 0.25 % copper to rails and rail fastenings has not been found satisfactory in every respect so that this measure has again been abandoned. Rail S 64 is exclusively pro-

life of rails and fastenings are protective coats of paint as well as varnish-like plastic coatings and, in the case of spikes, hot-dip galvanisation. Coats of red-lead, tar or asphalt products and, in recent years, anti-rust oil have been tried out. For the rails, excellent experience has been gathered with a system consisting of one or two red lead primers and two finishing coats of a coal tar pitch solution. Where the red lead primers had been omitted, sub-surface corrosion

was frequently encountered after a time. The same protection can also be recommended for the spikes. These coatings are of course not able to prevent corrosion entirely; but they are already valuable if they are able to delay the onset of corrosion

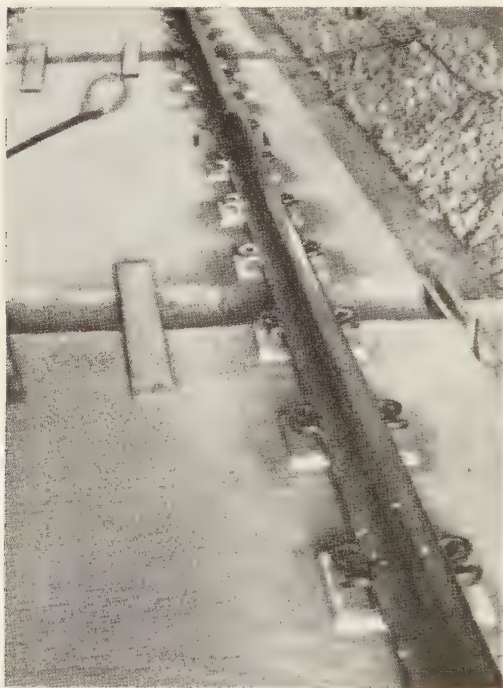


Fig. 9. — Sleeper-less permanent way for tunnels laid in the Hengstenberg Tunnel on the Hagen-Brügge line. S 64 rails fastened with twin elastic spikes Dna 6. The recesses on the concrete slab contained gauge keeping sleepers.

to such an extent that the rails need not be removed before the wear of the rail head has reached the permissible maximum value.

f) *Ventilating plant designed to facilitate maintenance work in tunnels.*

Only two among all the railway tunnels in Germany are provided with an efficient

ventilation plant so that, in long tunnels filled with smoke, conditions for works of all kinds are unsatisfactory. With permanent way renewal works, the application of mechanised methods in tunnels is not practicable, if only because of the limitations imposed by the tunnel cross-section. Such work must therefore be carried out manually by strong teams of gangers, often under indifferent lighting conditions. In order to create tolerable conditions for such work, a special ventilation plant has been designed which is able to remove smoke gases even from fairly long tunnels within a short time.

This plant consists of an air screw of about 2.5 m diameter (fig. 10) which is mounted on a mobile truck and driven

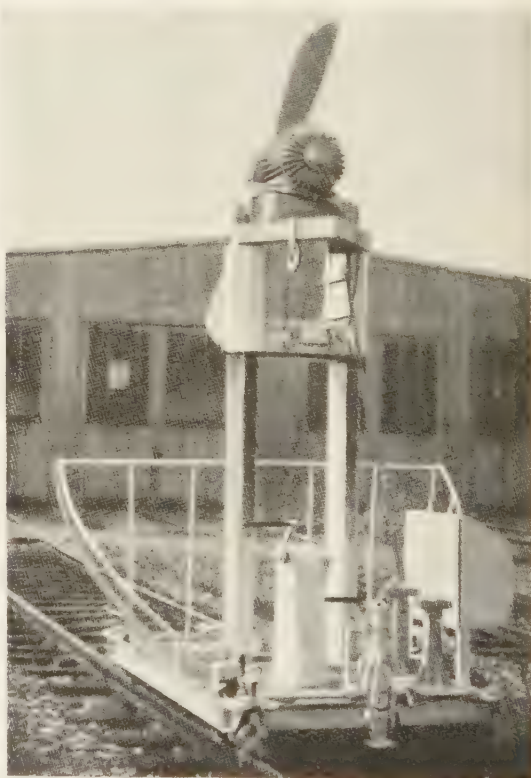


Fig. 10. — Tunnel ventilation plant with air fan of about 2.5 m diameter.

by a 26 kW electric motor. The latter receives its current from a 35 kW generator mounted outside the tunnel. The fan is placed on the blocked track some 200 m or more from the working site. In the absence of wind outside, the air screw, rotating at about 1 000 r.p.m., is able to generate in a double-track tunnel an air current of a velocity of 2.0 to 2.5 m per sec. When employed in the 2 652 m long Rudersdorf Tunnel on the heavily used Ruhr-Sieg line already mentioned where ventilation conditions are particularly unfavourable, this plant was thus able to remove the smoke gases from the working site within 3 to 15 min, depending on the distance from the tunnel mouth and on the method of operation (suction or pressure). In this way, it was possible to obtain, with a mobile tamping machine, an hourly output of 80 m. Without the ventilation plant, the output would have been, at the most, half that figure.

Apart from permanent way works, the ventilation plant will of course also be very useful for tunnel inspections and other works inside the tunnel, and again for the forthcoming works of lowering the track and rehabilitating the tunnel in anticipation of the electrification of the Ruhr-Sieg line.

### 3. Future prospects.

When the « K » type permanent way, which had already been found extremely

satisfactory on open lines, was also introduced in tunnels (in spite of the large quantity of metal fastenings required for it), it provided a demonstration of the fact that the advantages of indirect fastenings increase with the likelihood of a need for frequent renewals of all or some of the rails.

On the strength of experience so far, it can already be stated that the heavier, and therefore less frequently renewable, « Hf 64 » type permanent way is likely to be found satisfactory in straight and slightly curved track under normal traffic loads. It remains to be seen, however, to what extent the elastic spikes, once removed and reinserted, are liable to lose their firm seating and holding pressure so that the adhesion in the sleeper, and thus the tensioning of the rail, might become inadequate after repeated removals. If this should lead to premature track maintenance work, the advantages expected from this type of permanent way would, at least partly, be lost again.

In the case of sleeper-less track, where the elastic spikes are fastened with corrugated beechwood dowels, impregnated with tar oil, another open question, in addition to the final assessment of this type of track which is not yet possible, is whether it will be possible, in the course of further development, to make more use of plastics for permanent way in tunnels.

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# New Czechoslovakian system for periodic traffic control,

by Jan SUCHÁNEK,

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(*Deutsche Eisenbahntechnik*, No. 8, August 1960)

## INTRODUCTION.

The Prague Transport Research Institute has been working for some years on perfecting a continuous system and a « periodic » system of traffic control.

This work has led to installations which are likely to be introduced in the future on the lines of the Czechoslovakian State Railways. These are a continuous system with 4 indications making use of track circuits supplied with coded A.C., intended for use on lines equipped with the automatic block or electrified lines, as well as the periodic control system (« by points ») which is to be installed in a simplified form on the other lines.

The periodic traffic control is the particular concern of this present article.

Starting from the original request to transmit 7 different signal aspects to the trains, which was satisfied as long ago as 1596 in the 7-indication model, the Institute went on to a system which transmits 4 indications at certain selected points (1958) and then to simplified periodic control (1958), which transmits to the train from important signals on the line an impulse which is used in the driving compartment to give optical and acoustical warnings (distance signal, main signal, order to slow down, etc.).

We will not describe the old system with 7 indications because of its complication, although the prototype was successfully tested on a train. We will describe both the systems of simplified control at periodic points with 4 indications.

The common characteristic of the two systems of periodic control designed by the

Transport Research Institute is the method of transmission from the line to the train, which makes use of static indicators sensitive to variations in magnetic fields, the design of which is based on a Czechoslovakian patent No. 83037 of 1950. The working of this indicator will be explained in a special article.

The principles, which the Transport Research Institute elaborated for perfecting periodic traffic control can be summed up by the following points:

1) absolute certainty of working and protection for cases of mechanical or electrical defects in the installations;

2) assured working from the lowest train speed to the maximum, without any material contact between the moving parts of the train and the fixed parts on the track;

3) the transmission elements fitted on the lower part of the train, as well as the parts fitted on the track must be protected from contacts, must not include any moving parts, must stand up to vibrations as well as harmful atmospheric influences (damp, low and high temperatures, rays of the sun) as well as the effects of chemically active surroundings if necessary;

4) if anything is wrong with the installation, it must be noticeable immediately; should they occur, defects must act in the sense of increasing the safety factor;

5) the installation must be usable on all types of track, i.e. also on lines with metal sleepers, long welded rails, etc.;

6) all the parts must be capable of being made in Czechoslovakia of the materials laid down;

7) the capital and maintenance costs must be kept as low as possible, the installation of the equipment simple, and repairs easily made.

Although some of these conditions are contradictory, they were satisfied to the greater part in the installations designed.

### 1. The idea of traffic control in general and the justification for using systems of periodic control.

By traffic control we mean in the wide sense an installation which checks that the train is being driven in conformity with the indications given by the signals, and if not, stops the train if the driver is not able to do so, for any reason.

Often traffic control is associated with cab signalling, which is of particular importance when visibility is poor, or when poor visibility conditions are caused by fog, snow storms, heavy rain, etc. The action of a traffic control installation extended in this way, especially when it plays a direct part in the driving of the train, i.e. stops it should anything go wrong with the driver and prevent him from acting on a stop signal, can be considered as the logical end of operations concerned with the routing of the train. In its simple form the installation draws the attention of the driver to the fact that he is approaching a fixed or mobile signal, a distant signal, etc., or any other important circumstance, and it is also associated with an automatic stopping device which comes into action when the driver is not able to drive the train under the set conditions.

According to the method of transmission used from the track to the train, these installations are divided up into continuous control and periodic (at fixed points) control.

The continuous system is characterised by the use of coded A.C. of invariable frequency (or several circuits of different frequencies) running through insulated rails.

These currents give rise to an alternating magnetic field which induces in 2 receiving coils fitted on the locomotive frame, before the leading driving axle, a voltage which is

taken to the inlet to the equipment amplifier on the locomotive. After amplification and decoding, this voltage causes the appropriate light signal to appear on the cab signals.

Continuous traffic control can as a rule work in conjunction with the automatic block systems.

It is clear from the above report that with such an installation it is necessary to assure a satisfactory isolation of the track. Maintenance of such a condition is however fairly costly and often comes up against different difficulties, as has been confirmed by the experience with other installations in which isolated rails and track circuits are used. Welding of the rails, track installations and the very long rails which are being more and more used make it difficult to use track circuits, and consequently devices for continuous traffic control, especially on account of the fact that these require insulated rail joints which, as experience has shown, are very subject to trouble in the case of long welded rails.

It is always necessary to separate by means of isolated joints the running lines of station installations, so that the working of continuous traffic control cannot be obtained by any simple means. The same applies in the case of using systems with unlimited track circuits.

With the continuous systems, transmission takes place permanently during the whole time the train is travelling over the section so equipped. On the other hand, with the periodic systems, the transmission of information only takes place at a given point on the section, i.e. at intervals.

The periodic systems can make use of a whole series of transmitting devices. It would lie outside the scope of the present article to enumerate all these mechanical, electro-mechanical, optical, inductive, induction and resonance, high frequency, and special systems using for example ultra-sonic or radio-active rays.

The two groups of traffic control installations mentioned above have their advantages and drawbacks. For example, with the continuous system, the constant trans-

mission and the use of track circuits enable a train to see that the section it is entering is already occupied by another train, which the periodic control system alone does not; however this problem also can be satisfactorily solved by what is known as the points stopping of trains or by means of axle counters.

One important consideration is that periodic systems can function without insulated rails and are in general less costly both as regards first costs and maintenance. Another advantage of these systems lies in the fact that in many cases, it is possible to use on the track passive elements (i.e. not requiring any supply of current to feed them) or even transmissible elements such as resonance and absorption circuits, installations supplied by induction with the source of supply on the locomotive (as for example in the Swiss Metrum system), or permanent magnets (as in the simplified Czechoslovakian system of the Transport Research Institute).

In view of the properties we have listed above in the case of periodic control systems, it is not possible for the safety technique of the railway to give up using them for the moment, and in spite of certain imperfections, their development, perfecting and progressive use must not be impeded.

It is generally recognised that railway vehicles lend themselves particularly well to the application of traffic control installations, seeing that the character of the operating is such that after the driver has been found to be incapable of carrying out his duties, there is still sufficient time to stop the train automatically, which would be impossible, for example, with road vehicles, not only on account of their speed, but also because their direction would have to be controlled in some way.

It is to be hoped, however, that in spite of this apparently insurmountable obstacle, the development of safety techniques will also be pursued in the case of road vehicles, and that the experience obtained with modern systems of continuous traffic control in the case of railway will in fact contribute to assuring safety of life, health and stock in the case of road traffic.

## 2. Static indicator sensitive to variations in the magnetic fields.

In studying the new installations for periodic traffic control, it is logical to require these to harmonise with the operating conditions of the railway in question, with perfect adaptation to the functioning of the other signalling installations. In addition, first and maintenance costs, the possibilities of mass production, etc., all play an important part.

One essential quality is security of functioning, which is closely linked up amongst other things, with the question of the use of moving parts, in particular parts likely to suffer wear, which modern safety technique avoids as much as possible. Likewise, details with heated cathode (electronic tubes, thyratrons, etc.) are undesirable. The important circuits must be so designed that if anything goes wrong or a short circuit occurs, the operating will not be endangered in any way, and it must be easy to discover when anything has gone wrong, or this can be signalled by some special device. The installation must be protected from vibrations and harmful atmospheric conditions (wide temperature variations, damp, etc.) must be limited as far as possible. However, it is not unusual for a compromise to be agreed in reaching a solution.

Although there is a whole series of systems of periodic traffic control, the technique of signalling has not yet had the last word, and all new knowledge in the field of electrotechnique which can be made use of for designing traffic control installations will assist the future efforts of technicians.

The Czechoslovakian invention known as "indicator sensitive to variations in the exterior magnetic fields", for example, has led to a new conception of systems of periodic traffic control, which has not yet found its equivalent. The transmission of the information from the track to the train works well under the influence of continuous magnetic fields as in other systems, but use is made as receiver on the locomotive of a static indicator of variations in the magnetic fields, which forms the base of the aforementioned patent.

All subsequent improvements are also protected by Czechoslovakian patents. The results of 10 years work of perfecting the indicators show that this apparatus will become an important element in the field of mechanisation and automation, but even more so in protecting the running of the trains.

This indicator was the subject of a report given by the author to the First Congress of Czechoslovakian Physicists at Prague, in

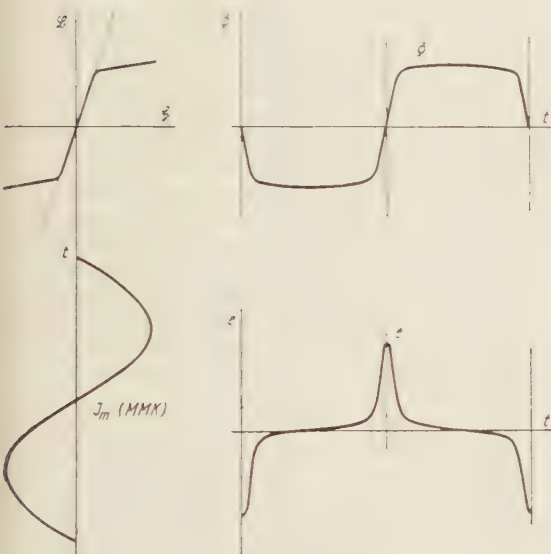


Fig. 1.

1957, and is well known in professional circles as a result of several articles which have appeared in the technical and daily press. For the sake of completeness, we will give once again briefly the principle applied.

The indicator is essentially a special transformer with a magnetic circuit of unequal section constituted in part or in totality of a ferromagnetic material which is easily saturated (alloys having high permeability). The primary winding, connected to the D.C. source, is generally not arranged coaxially with the secondary winding. The latter usually consists of 2 coils, coupled in series and fitted on the part in permeable alloy

of the reduced diameter core. The current passing through the primary coil sets up an alternating flux closed by the appropriate saturated part of the magnetic circuit as well as by the air, in the form of the leakage flux.

By selecting a regulating current of a value such that saturation is pushed beyond the bend of the curve of magnetic induction, the variation in the time of the magnetic flux has approximately the form of a trapeze, and the secondary voltage has a rate in the form of a surge, seeing that its curve represents the derivation of the magnetic flux  $\Phi$ .

Fig. 1 shows the formation of the pointed curve of voltage when the magnetomotor force (MMK) has a sinusoidal pattern, under the hypothesis that the hysteresis is ignored (the hysteresis loop is infinitely narrow).

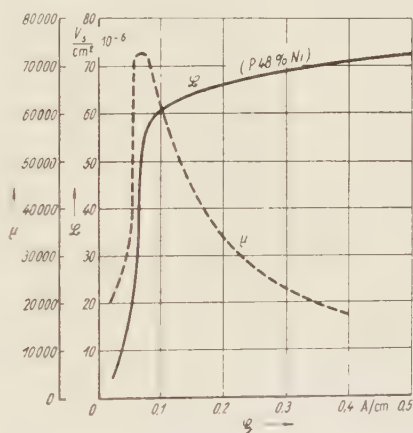


Fig. 2.

An analysis of the curve of the voltage shows that odd harmonics are produced, in particular of the third order. At the audible frequencies which are used for the excitation, the variation in the outlet voltage already approaches the sinusoidal form.

Under the action of the exterior magnetic field on the system in question, this outlet voltage is reduced. This fact may be explained more or less by the differential per-

meability, which is defined by the relation  $\mu_{rev} = \frac{d\mathcal{L}}{d\mathcal{H}}$  applying in the case of asymmetrical alternating magnetic induction in the presence of a presaturating continuous magnetic field.

It is known that in the case of an ideal material,  $\mu_{rev}$  attains its maximum for an intensity of the magnetic field of  $\mathcal{H} = 0$  and then diminishes rapidly as  $\mathcal{H}$  increases. With any actual material (for example an alloy of P with 48 % Ni)  $\mu$  reaches its maximum at low values of  $\mathcal{H}$  owing to the curvature of the magnetic induction curve  $\mathcal{B} = f(\mathcal{H})$ , however the lowering of the permeability is equally important in this case (fig. 2). When  $\mu$  diminishes, the coefficient of flux linking between the primary winding and the secondary winding is also reduced, which can be demonstrated by mathematical or graphical means.

The drop in the outlet voltage can be caused by bringing up a magnet or exterior electro-magnet to any pole, and it is then possible to use the neutral indicator modified in this way in different forms of application. It is, however, often useful to make the outlet voltage increase by a modification of the exterior magnetic field. This can be done by placing in the immediate vicinity of the indicator one or more permanent auxiliary magnets. Their effect is compensated, or reinforced by the exterior magnet, which increases or reduces the outlet voltage according to whether its polarity is identical with or opposed to that of the auxiliary magnets.

Whilst indicators of this type could not, to begin with, develop more than a very feeble power at their terminals, it was subsequently found possible, thanks to a suitable design as well as to improvements and additions, to obtain a power several times greater, which in the case of certain applications made it possible to make the power indicator function directly in combination with the relay without having to use a thyatron or electronic amplifier or some such similar device.

Another fundamental modification was the introduction of a reactance, which led to

the making of static rocking indicators. These work like selector switches, controlled from a distance of several decimeters by a magnetic field without any material intermediary and consequently without any parts likely to become worn (armatures, springs, contacts) as well as without electronic vacuum tubes, thyatron tubes, etc.

The constitution of the transformers and the low power needed makes it possible to seal the indicators in suitable boxes by means of some run in material after air drying. In this way, sufficient resistance to humidity and the harmful effects of any chemically active surrounding is obtained. They are inexplosible, and require very little energy or space. One precious quality of such apparatus is its resistance to vibrations and the practically endless useful life.

Their use in installations for periodic traffic control in the form of selector switches controlled by a magnetic field is particularly useful because they allow of an assembly which functions in the direction of increased safety. When the main relay working in conjunction with the indicator cuts out during working, an indication is given.

In this case, the condition of safety is complied with just as much in the case of an interruption or short circuit in the winding as in the case of a breakdown in the current, seeing that all these upsets lead to the fall of the armature of the main relay, which assures the necessary safety. Indicators of this type can signal any given physical phenomena, which can be linked up with a modification of the intensity of a magnetic field. Under laboratory conditions, sensitivity in the case of variations in the exterior field exceeds  $10^{-3}$  A/cm. However, owing to the possibility of the appearance of fortuitous disturbing fields, this sensitivity is far from being completely utilised for the needs of safety technique.

### 3. The 4 indication periodic traffic control system invented by the Transport Research Institute.

This system of traffic control is based on a combination of magnetic fields set up all

along the track by means of 2 electro-magnets in concordance with the signal, acting by means of this combination on the 2 static indicators, mounted on the lower part of the train equipment, by modifications in the magnetic fields.

In addition to the electro-magnets mentioned, 2 permanent magnets are also installed at each information point on the line.

These 2 permanent magnets always play a part in the transmission of the signal indication, in conjunction with one or two electro-magnets, the latter being connected by a cable with 3 conductors.

On the train, high power static outlet indicators are fitted which act in conjunction with the main relay as will be explained in greater detail further on.

The whole installation includes apparatus installed on the track or in the appropriate signal box, and the parts fitted on the train. The distribution of the signal repeating points and the method of functioning of the installation were designed in collaboration with Traffic Department specialists on the following basis:

At the first signal, the driver gets a brief acoustic warning which draws his attention to the coming distant signal. The actual indication of the signal, which is identical with that shown by the signal itself, is first of all transmitted to him at the information point immediately behind the distant signal. It is repeated again at one third of the distance between the distant signal and the home signal and also at some 100 m before this latter.

The track magnets, as well as the electro-magnets fastened to the sleepers, have the same aspect: these are prisms bedded down with chamfered frontal facets to avoid them being damaged by light objects which may chance to be outside the vehicle gauge.

The permanent magnets of cylindrical form (usually 2 in number) with common pole shoe, and protected by a duralumin cover are made of special "Alnico" steel, or else ferrite magnets are used containing baryum, which are noted for their great stability. The electro-magnets also have cylindrical cores and the same polar parts as the permanent magnets. The consumption

of electricity is about 15 W per electro-magnet.

Each information point has apart from the 2 permanent magnets, 2 self contained electro-magnets which are supplied by a three-wire cable by the contacts of the corresponding signal box levers with D.C. current from a battery of accumulators constantly plugged in.

At the information point before the distant signal, the electro-magnets are replaced by 2 permanent magnets.

The equipment fitted on the locomotive consists of the following 3 main parts:

a) the receiver system, Czechoslovakian patent No. 90494, consisting of static power indicators sensitive to the magnetic fields;

b) the relays system, with the signal light aspects repeater, acoustic warning, vigilance button, pressure switch and electro-magnetic brake valve;

c) the three phase 500 cycles generator for the excitation of the indicators.

The whole installation is supplied either by the battery of accumulators of the train, or directly from some such source of current as a turbo-dynamo.

We will give a general description of the working of the installation on the locomotive. When the signal aspect "green" (line clear) or "yellow" (caution) is transmitted, the electric klaxon is sounded briefly (about 1/2 sec.) whilst in the case of transmission of the aspects "yellow-yellow" (branching) or "red" (stop), it sounds continuously until the driver presses the vigilance button. He must however do this within 6 seconds, or else the compressed air brake valve will open and the train will stop.

If the button is pressed in time, the white re-setting light lights up and the driver continues to drive the train as usual, i.e. he brakes or stops the train in the usual way. The installation is then able to receive a new signal at the following information point.

For the reception of a "green" signal aspect (line clear), the intervention of two indicators is necessary. Before another aspect can be transmitted, the previous one is automatically cancelled by 2 track

magnets which, as a safety measure, transform each preceeding indication into «stop», this being afterwards changed to the appropriate signal indication from the combination of the fields formed by the track electro-magnets as a function of the true position of the signal.

The breaking or short-circuiting of the

reaction (corresponding rectifiers  $G_4$ ,  $G_6$ ) and the double smoothing coil D. In one of the 2 D.C. windings is inserted the magnetic induction of the stabilizer which compensates the fluctuations in voltage of the current supply by  $\pm 20\%$ , as a non-linear element of the blocking cell  $G_3$ . The relay  $R_3$  has the purpose of detecting any fault

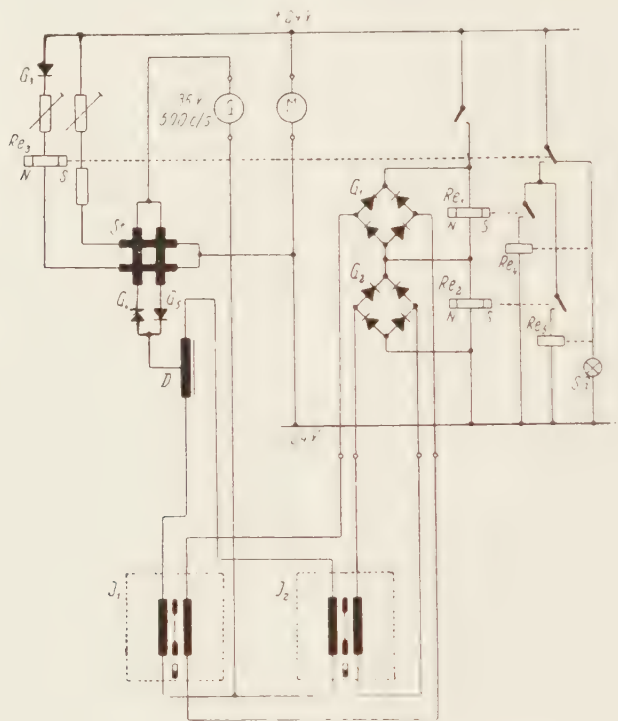


Fig. 3. — Diagram of the traffic control device with 4 indications.

main circuits of the installation leads to the appearance of a more restrictive signal aspect (for example, instead of «green», «yellow» and instead of «double yellow» «red»).

The primary windings of the 2 indicators  $I_1$  and  $I_2$  (fig. 3) are supplied with 500 cycles A.C. at a tension of 16 V by the motor-generator group M-G through the intermediary of the magnetic transductor stabiliser ST, which functions with internal

due to the cutting of this circuit, signalling this by means of the incandescent lamp SG.

The outlet voltage of the inductors  $I_1$ ,  $I_2$ , which is rectified by the rectifiers  $G_1$  and  $G_2$ , is sent directly into the exciter coils of the main polarised relays  $Re_1$  and  $Re_2$ , which work according to the principle explained in the patent papers PV 1813-56.

The idea is based on the appropriate user

of 3 states of electric tension of the indicators. These are fitted with compensating magnets and give at the outlet a nominal voltage corresponding to the influence of this invariable field if there is no other outside field.

When the system is subjected to the influence of an outside magnet, whose polarity is such that it reinforces the action of the auxiliary magnet, the outlet voltage is reduced. If the exterior field acts in the opposite direction, the voltage increases. The polarised relays  $R_1$  and  $R_2$  are regulated in such away that at the nominal voltage (the indicator not being under the influence of the exterior field), owing to the small air gap, their armatures remain in the position to which they were previously put, for example they remain attracted.

If the nominal voltage diminishes under the influence of the exterior field, the relay armatures fall and remain in that position even when the influence of the exterior magnet has disappeared (the magnet being further off), because the nominal voltage is not sufficient to reactivate them. It is only when, under the effect of the exterior field acting in the opposite direction, the voltage to the indicator increases, that the armatures are attracted and remain once again attracted to the nominal voltage.

The attraction of the armatures of the 2 main relays controls the presentation of the most important signal aspect « green », whereas if they fall, the aspect « red » is shown. If the first armature has fallen, but the second remains attracted, or vice versa, we get the aspects « yellow » or « double yellow » respectively. If, owing to a breakdown in the supply to the indicators, the armatures fall, or if anything goes wrong with their windings due to a short-circuit or cutting out of the excitation conductors, this will always lead to the appearance of a more restrictive signal indication.

The other relays are auxiliary relays which, according to the signal aspect transmitted, work the klaxon, the lights of the signal repeater, as well as the brake valve circuit, and make it possible to put the installation out of circuit when the driver has pressed the vigilance button within the

6 seconds following the acoustic warning given by the klaxon as a function of the modification of the signal aspect. This part of the installation is the same as in other traffic control systems, and we will not describe it in detail.

Four-aspect periodic traffic control facilitates and completes the work of the driver, as safety of working is thereby assured should anything go wrong with the driver; in addition, it improves the economics of driving in the sense explained below.

The warning signal which, on a line which is not equipped with traffic control, tells the driver he is approaching the distant signal, forces him to reduce his speed prematurely, because as a rule the signal aspect is still not clearly visible when passing the distant signal. For example, if the signal is showing the indication « entry on to a branch line », it is not necessary to stop, and the speed need not be reduced as much as for the signal « stop ». As the traffic control installation shows the aspect of the main signal in the driver's cab as soon as the distant is reached, this drawback is eliminated. In the same way, if the signal changes from stop to line clear, and if this change takes place before the second information point, the driver is warned in time, so that he has not got to reduce his power by braking, which always involves a loss of power, nor will he increase the journey time by any unnecessary slowing down.

#### 4. Simplified periodic traffic control system of the Transport Research Institute.

The economic estimates showed that the cost involved in the cables for supplying the track magnets was an important item in the overall costs in the case of the above system. This drawback is common to all systems which make use of active components on the track. In 1958, therefore, an endeavour was made to perfect a simplified periodic control system. This no longer transmits the different signal aspects, but calls the driver's attention by optical and acoustic signals to important situations on the line. This system also controls the

vigilance of the driver, as in the 4 indication system.

The parts fitted on the track are passive elements, permanent magnets housed in suitable boxes fitted to the sleepers, so that nearly all the cables, current supplies and switching devices acting as a function of the signal aspect become superfluous.

box according to the direction of running, and which include a "supply" part and a "relay" part.

In the control box is the main switch, the fuses, the direction changeover switch, the cutouts for the guard's key and the meter. The other parts, i.e. the vigilance push-button, the klaxon, the 2 aspect signal repeater

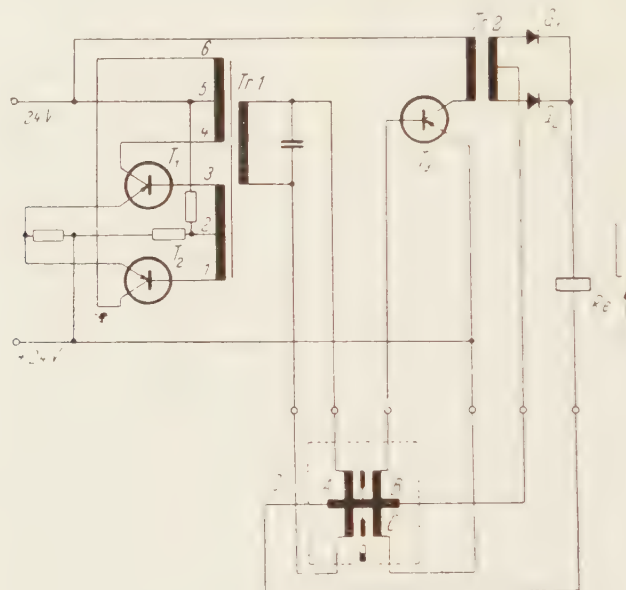


Fig. 4. — Diagram of the simplified discontinuous control device.

The actual transmission of the warning signal on the line to the train takes place essentially in the same way as with the control system described above, but in the new installation a whole series of improvements has been introduced.

For example, static reactance indicators have been used, and the rotary current converter has been replaced by a transistor unidulator. The general arrangement was dictated by the need to simplify the 4 indication periodic control of the traffic. The receiver element of the locomotive equipment consists of 2 static indicators which can be connected separately to the control

(white light for working and yellow light for warning) as well as the electromagnetic valve connected to the pipe of the continuous brake and the pressure switch are fitted at suitable points.

An essential part of the receiver is, once again, the static indicator sensitive to variations in the magnetic fields. Its design is based on the Czechoslovakian patent No. 83037, as well as the more recent patents 98404 and 91221.

It is in principle a rocking power indicator of the variation of the magnetic fields, including the reactance and a compensation magnet. The choice of a suitable ratio

between the number of turns of the winding and the corresponding dimensions of the core which is made of high permeability alloy, as well as that of the compensation magnet allow the receiver to rock. This is shown externally in the form of 2 stable electrical conditions to which the system can be brought under the effect of the exterior field, each of these states being characterised by the direction of the exterior field. The indicator is excited by 2 000 Hz A.C.; at the outlet the voltage is still A.C., but for the reaction, D.C. is necessary.

The transistors  $T_1$  and  $T_2$  (fig. 4) work as a double action generator in coupling with transmitter in neutral. They are supplied with D.C. from a turbo-generator group or by an accumulator. The collectors of the two transistors supply A.C. to windings 4, 5 and 6 of the transformer  $Tr_1$ . The windings 1, 2 and 3 allow the reaction on the bases of the transistors. The exciter coil A of the indicator I is connected to the outlet winding of the transformer  $Tr_1$ .

The secondary winding B is connected to the transmitter of another transistor  $T_3$ , which works as a low frequency amplifier with transmitter in neutral. This amplification gives, with the assembly in question, sufficient reaction at the receiver, so that the rocking is obtained. The outlet of the amplifier is designed like a transformer outlet and the secondary winding of the outlet transformer supplies, through the diodes  $G_1$  and  $G_2$ , the relays Re and the reaction winding C of the indicator I.

When at rest, the receiver is in the through position, so that the outlet winding B gives sufficient power for the transistor and consequently also for the reaction. Current circulates through the coil of the relay Re, so that its armature is attracted. When the indicator is affected by the magnetic field of suitable polarity of the track magnet, its outlet power is reduced for a short time, which is sufficient to make it rock into its second position, the blocking position. The outlet power of the receiver is then reduced and is no longer sufficient to excite the transistor  $T_3$ , and as the current in the reaction winding and in the relay Re diminishes, the armature of this latter falls.

As can be seen, the outside magnetic field supplies the impulse to detune the reactance, so that the time constant of the relay Re is not of capital importance. Rocking in the through position takes place when the vigilance push button is pressed at the right time (this is not shown in the diagram), which for an instant sends current from the source of supply into the winding C of the receiver as well as into the relay Re, which attracts. In this way the installation is reset.

If the driver does not press the button within 6 seconds, the electro-magnetic valve opens the continuous brake pipe, thus causing the train to stop. If the button is pressed too late, the white light for resetting the installation appears, the acoustic warning is cut, but automatic braking can no longer be prevented.

The preliminary condition for the closing of the brake pipe for restarting is the attraction of the relay the coil of which is in the circuit of the pressure cutout, meter and key operated cutout. Automatic braking are all recorded, the O.K. and direct intervention of the guard being necessary, as he resets the installation, by means of his key after the train has been braked. We will not describe the auxiliary circuits, which we feel are well known.

An important advantage of the simplified traffic control system is the multiplicity of cases in which it can be used, as such an installation can be coupled up with any protective installation, the safety of which it will effectively increase by very simple means. The track magnet is fitted at the place where the warning should be given to the train, for example 75 m before the distant signal. Warning of any special signals, for example an order to slow down on account of work on the line, can be given by means of a portable magnet.

## 5. Conclusions and perspectives.

The periodic traffic control systems of the Transport Research Institute of the Czechoslovakian Railways, which have been briefly described above, are undoubtedly a contribution to the technical development of such important equipment for railway transport.

The method of transmission used in these installations is a new one and advantageous from the point of view of safety because the lower limit of the speed of reception of the impulses can be taken right down to zero and it is possible to install a safety arrangement which, should anything go wrong electrically, such as a short circuit or cut in the supply, ensures that there is no danger to the safety.

The indicator has been considerably improved whilst the equipment was being perfected, seeing that the outlet power has successfully been considerably increased so that the installations can function without electronic tubes (for example, the 4 indication control system of the Transport Research Institute). The use of semi-conductors has made it possible to construct a rocking circuit, and consequently to replace the highly sensitive main relay by an ordinary relay of robust design. The transistors have also contributed to solving the problem of a source of A.C. supply on the train, necessary for the excitation of the indicators.

These installations of the Research Institute, as well as several others which are still in the laboratory stage, form an important contribution to the general design (arrangement and method of functioning of the different parts) of traffic control equipment, especially as regards the realisation of a better and more convenient method of

controlling the vigilance of the driver than the method generally used of working a push-button. The Transport Research Institute has in view installations which will enable the driver to confirm by some natural gesture the reception of the signal aspect or the warning transmitted (without any corporal contact) which he would naturally do, for example leaning over to look out of the window at the line at the critical moment, i.e. when approaching the signal and when his attention is drawn to the fact by the optical or acoustical devices of the traffic control equipment.

The perfecting of the installations described for the periodic control of the traffic by the Transport Research Institute, and in particular the method of transmission of the information from the line to the train has been used in projects for other safety installations, both in the case of railway transport — for example the automatic announcing of the end of the train (tail signal), working the points from the locomotive in motion (mining and ironworks lines) — and in the case of road traffic where to date technical safety installations have been very rare. For example it is a question of installations indicating the parking of road vehicles, and a method of automatic control without contact of light signals by the road vehicle whilst running at cross roads or in one way streets. In addition, the indicator itself has numerous uses in general electro-technics.

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## Railway brake.

# Possibilities of increasing its power and their consequential effects,

by Ernst MÖLLER, Munich.

(From a Lecture given at the Institute of Public Lectures of the Technical University of Berlin, on the 24th November 1959.)

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### 1. The rail.

#### The part it plays in transport.

As a result of the economic conjuncture, the alternative « rail or road » has turned, almost unnoticed, into the solution « rail and road ». But an economic revival may result in saturation of all the different methods of transport to such an extent that the capacity limits of the partners become apparent and one has to turn his thoughts to the possibilities of each of them.

The increase in the density of population — not only in the industrialised countries — and the ever increasing well-being of the individual as a result of the penetration of technical progress into all forms of life, follow, in spite of occasional fluctuations, an evolution at practically a logarithmic rate which the weak-hearted can easily come to think of as an unhealthy phenomenon: this general law also applies to the development of transport.

#### 1.1. Road, rail, air transport.

At the present time, it is seen that the individual vehicle, the motorcar, is experiencing ever greater difficulties, not only at the peak points of traffic congestion, but in ever widening zones, because the roads are becoming too narrow, although the flexibility of each vehicle is constantly being improved by increasing its powers of acceleration, due to the perfecting of the engines,

and its power of deceleration by its brakes. Attempts are being made to guide this evolution, which tends to be a somewhat negative one, by limiting private initiative and by measures applicable to the collectivity. The signals, the traffic signs, one way traffic, have become obligatory; slow and fast vehicles of necessity form into slow and fast columns of traffic on the right and left sides of the road, often simply because they have become resigned to it. But even with such collective formations, the unrepentent individualist, whether he goes too fast, or too slow, or as he thinks fit, is a disturbing factor. For many years, the average speeds have in fact tended to decline, in spite of the improvements made to the vehicles.

It is interesting to observe that above a certain traffic density, with inadequate roads, road transport has had to have recourse to collective measures, such as have been the practice on the railway right from the start, which have been studied and perfected to such an extent that it is possible to claim that railway transport is an ideal form of collective transport under central management: grouping according to kind of traffic, ideal route protected by signals, assured by the wheel flanges, smoothness and independence of atmospheric conditions and other outside influences, central control to the nearest minute with timetables valid for six months. If the vehicle and the passenger are rigidly controlled within this scheme, the railway on the other hand ma-

kes it up to the latter by allowing him the greatest personal liberty on the vehicle itself: he is able to walk about, read, take meals, take his luggage with him, including his car; the railway remaining responsible for the journey. Here, once more the passenger becomes an individual.

The transport difficulties experienced owing to the limited possibilities of the road can be paralleled in the case of air transport. The ultra-rapid airplanes have already given up the domains assigned to them. Aircraft with a speed of only 300 km/h are, so to speak, already out of fashion. In the case of faster aircraft, the continents themselves have become too small. The airports, the flight routes and the landing tracks are still in most cases adequate for the present air traffic, although it is expected that by 1960 there will be some 5 000 aircraft in use throughout the world. The development of civil aviation is making the position still more difficult. In this field, we are going to come up against the same troubles as on the roads, taking furthermore into account that air ports and air routes need a great deal more space than road and railway.

### 1.2. *The possibilities of the railway.*

Although the road haulier needs help and is always clamouring for new roads and a greater number of highways, and is trying to solve the problems of circulating and parking in working areas and built up areas, it is as well as to ask ourselves whether there are not any unused reserves on the railway from the point of view of the speed, train loads, train lengths and the density of the traffic.

The French showed not so very long ago that it is possible to run on an ordinary line with the usual type of catenary at speeds of 330 km/h, but they could not risk applying their brakes until the speed had fallen to 200 km/h. Express trains about 500 m long reach peak speeds of 140 to 150 km/h. On the other hand, goods trains with a load of 3 000 t and about 1 000 m long are now being run in Europe; in America the loads are as much as 8 000 and 10 000 t and the train lengths more than

2 000 m. The installations stand up to such stresses with axle loads of 20 t and over, as well as these high speeds. The lines are constantly being improved by the use of long welded rails without joints laid on concrete sleepers. The systems of signalling and automatic interlocking are constantly increasing the safety and flow of the traffic. Moreover, there is no question but that it is possible to build locomotives which will surpass the present performances as regards tractive effort, speed, and acceleration, so as to profit by these new possibilities. Apart from questions of financial output and the problems of getting out the timetables and the layout of the lines, railway transport from the pure traction point of view still has very interesting possibilities. But what will the idea of financial output come to mean in the technical studies of the future? What was in the past and what is today the « financial output » of motor transport, jet aircraft or atomic centres? As far as technique is concerned, financial output is only a temporary and relative idea.

### 2. Limits of brake power.

In these considerations concerning the evolution of railway transport, the brake plays a special key role, because the admissible speeds are based on the safety intervals between the home and distant signals and consequently depend on the effectiveness of the brakes.

The more effective the brake, the greater the running speed allowable. The better the brake works, the more it can be regulated, the shorter the necessary intervals between trains. This fact becomes the more apparent the longer and heavier the trains are.

The usual siting of the distant signal at 1 000 m in Europe therefore represents the maximum braking distance admissible. This spacing can only be increased to a limited extent because the distance of visibility then comes into the picture. It would no doubt be possible to replace optical vision by electronics and this no doubt will be done, but what would be the point if in Europe with its dense population, where the towns tend to grow into large urban regions — we have

only to think of the Ruhr — the stations to be protected become too close to each other.

The problems of the brake remain, and in principle they are two: the assured transformation of the kinetic energy of the moving train into heat in braking to a stop from still higher speeds or during prolonged braking on down gradients, and the uniform and exact control of these « energy conversion machines » especially on long, heavy trains.

We know that in fast braking, the stopping distance is the shorter the greater the deceleration caused by the brake, and that the deceleration can be the greater the better the coefficient of adhesion between wheel and rail. But the decelerating efforts applied to the wheel must never become higher than the adhesion between the wheel and the rail allows or else the wheels will begin to slide. The coefficient of slip which then occurs is lower than the coefficient of adhesion, the more so the higher the speed at which the jammed wheel slides on the rail. In practice, there is no need to make use of the whole of the coefficient of adhesion in the case of goods trains and slow passenger trains. The problems of adhesion only arise in the case of fast trains and railcars, but in this field they are of decisive importance.

### 2.1. *Braking speeds and distances.*

Figure 1 represents by a system of rectangular coordinates the distances as a function of the speeds for a group of curves calculated for decelerations of 0.4 to 3 m/s<sup>2</sup>. Amongst these, the heavy lines represent the curves of the braking distances used at the present time on the railway for goods trains, passenger trains, express trains, the Trans-Europ-Express (TEE) and a special railcar. All these types of trains are fitted with an up-to-date KE (Knorr-Einheitsbremse: standard Knorr brake) compressed air brake, according to their importance: the goods trains and passenger trains, a low power brake (KE-GP) because they do not run at very high speeds, and the others with more powerful brakes (KE-GPR) which make use

of practically all the adhesion between wheel and rail. In the case of the TEE rake and special railcar, we have also shown the curves for braking reinforced by magnetic brakes acting on the rails which give additional deceleration by friction on the rails independently of the wheels. The range of speeds has therefore been studied up to some 160 km/h.

### 2.2. *Theoretical considerations.*

To get some idea, at least theoretically, of the situation at high speeds, the measured curves have been extended by dotted lines, owing to their excellent concordance with the form of the theoretical deceleration curves. It is then seen that with a distance of 1 000 m for the distant signal, allowing for a margin of 10 % (braking distance 900 m) the goods trains could already at the present time run at 100 km/h, the passenger trains at 130 km/h, the express trains and TEE trains at some 150 km/h, and if they are also fitted with magnetic brakes, at about 160 km/h. The magnetic brakes used on the TEE can in fact be used just as they are on the fast trains. But the electro-magnets could be further improved in their action, as for example on the « VT-Cologne » railcar, so that it is possible to think of decelerations of some 2 m/s<sup>2</sup> even in the case of express trains, and consequently speeds of more than 200 km/h. It would appear therefore that the brakes are adequate, especially when we remember the reserve power in hand in the case of an increased warning distance of 1 200 or 1 500 m.

### 2.3. *Experiences at high speeds.*

Such is the theory, but how does the conversion of energy into heat really take place in the field of the idealised extension in dotted lines of the measured curves?

There is no difficulty in providing the necessary braking efforts with the compressed air railway brake. This is a brake with an accumulative effect, which can have practically as great an air supply on each wagon as desired, with which the desired braking

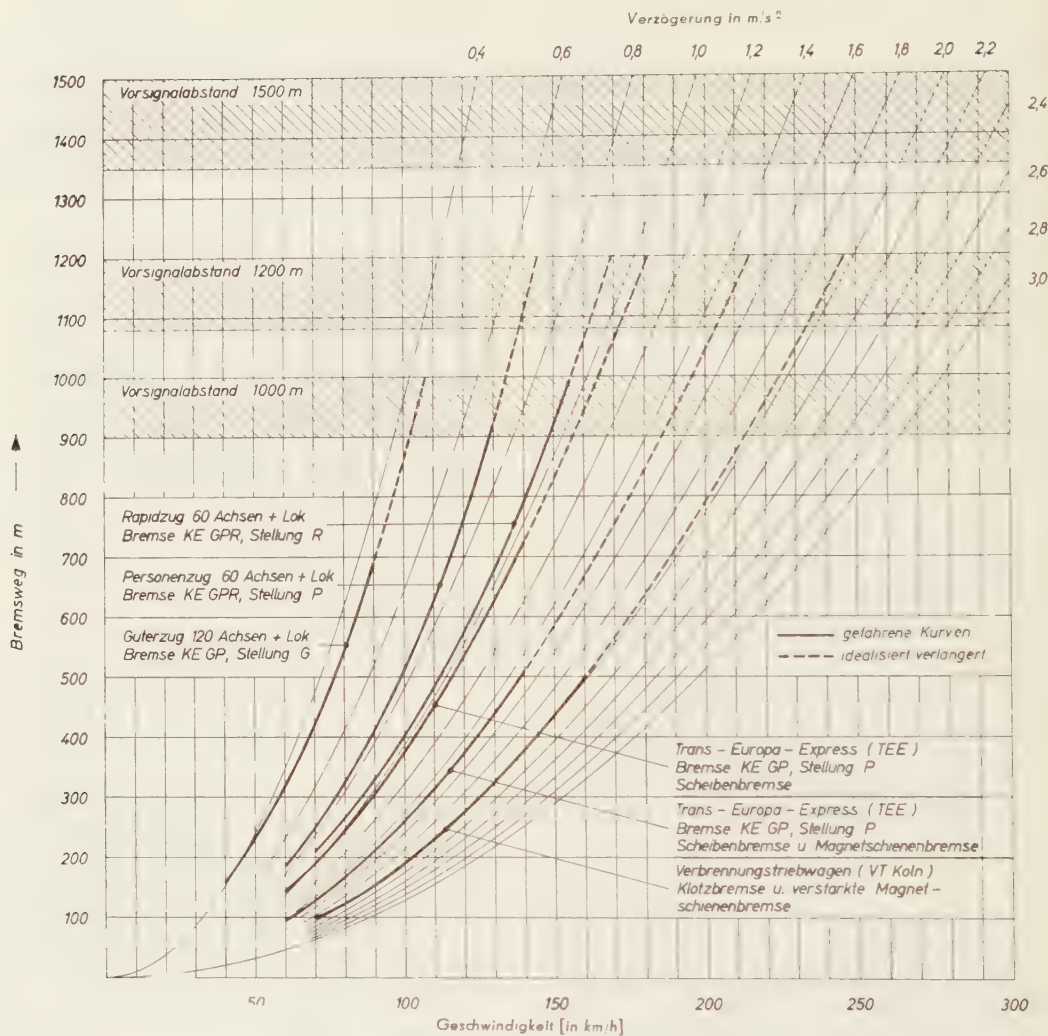


Fig. 1. — Braking distances of railway trains.

N. B. — Verzögerung in  $m/s^2$  = deceleration in  $m/s^2$ . — Bremsweg in m = braking distance in m. — Vorsignalabstand = warning distance. — Rapidzug... = fast train, 60 axles + locomotive. — Brems KE-GPR, Stellung R = KE-GPR brake, position R. — Personenzug... = passenger train, 60 axles + locomotive. — Güterzug... = goods train, 120 axles + locomotive. — Gefährte Kurven = curves of actual runs. — Idealisiert verlängert = idealised extension. — Geschwindigkeit = speed. — Trans-Europa-Express (TEE) Brems KE-GP... = TEE, KE-GP brake, position P, disc brake. — Scheibenbremse... = disc brake and electromagnetic rail brake. — Verbrennungstriebwagen... = railcar with thermal engines (VT Köln). Block brake and reinforced electro-magnetic rail brake.

effort can be obtained by a careful choice of the dimensions of the brake cylinder and the ratio of the rigging. On the other hand, it may be asked whether the methods generally made use of to destroy the kinetic energy by the friction of the shoes on the tyres or the brake blocks on special discs can still be used at such high speeds.

### 2.5. Braking to a stop.

The power in HP which the brakes of an axle have to stand during braking to a stop is a function of the axle load, the deceleration and the speed. Figure 3 shows what happens in the case of 10 and 20 t axle loads, i.e. in the case of fast passenger

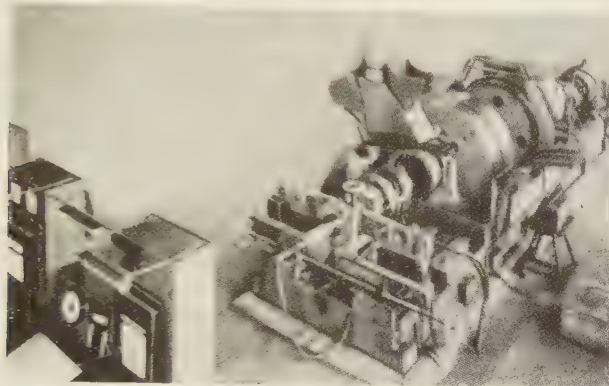


Fig. 2. — Test bench with revolving masses for studying brakes acting on the wheel, and disc brakes. Maximum running speed: 300 km/h; maximum kinetic energy:  $1.9 \cdot 10^6$  kgm.

### 2.4. The test bench.

The test bench with turning masses used for the investigation (fig. 2) has several groups of subdivided masses with which 72 different combinations are possible up to  $1.9 \cdot 10^6$  kgm of kinetic energy for a running speed of 300 km/h related to a railway wheel of about 1 000 mm diameter. Real wheels can be fitted at the end or discs inside the Prognys brake. The temperatures can be measured during braking at numerous places in the fixed and turning parts, and recorded at the same time as the braking efforts, the braking moments, the speeds of rotation and the braking distances. The average temperature at several points of measurement is taken, because during braking the maximum peak temperatures near the surface vary and are easily displaced.

coaches and slower wagons or heavy motor units. Two decelerations have been studied:  $1 \text{ m/s}^2$  which is just possible on good rails without having to make use of an anti-skid regulator, and  $1.3 \text{ m/s}^2$  which can only be obtained with perfect anti-skid regulators. The maximum values in HP are extremely high at the moment of maximum speed, but they decrease right down to zero with the speed. These powers must be converted into heat by the brake with the least possible wear.

Figure 4 shows the variation in the temperature in the case of braking without slip at 150, 200 and 250 km/h 3 mm below the surface of friction of the wheel in the case of a standard wheel of about 1 000 mm diameter with new tyres, on a « small wheel » of 600 mm diameter, and finally in the surface of a brake disc of 640 mm diameter,

like those used for standard wheels. The curves correspond to an average deceleration of  $1.2 \text{ m/s}^2$ , i.e. very close to the limiting stress. The figures relating to an axle load of 10 t were measured on a test bench; those corresponding to 20 t were determined on the basis of HASSELGRUBER'S calculations <sup>(1)</sup>

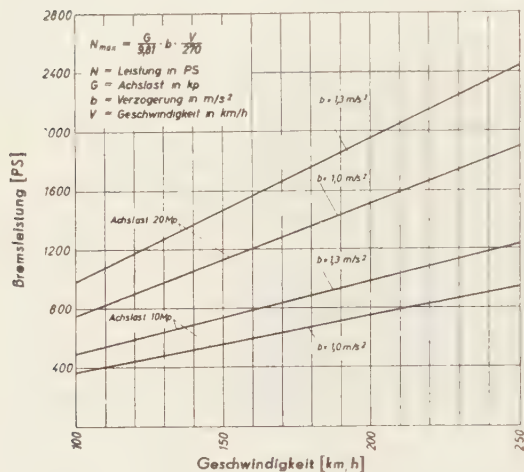


Fig. 3. — Maximum braking power per axle during rapid braking as a function of the maximum speed for decelerations of  $b = 1.0$  and  $1.3 \text{ m/s}^2$  and axle loads of 10 and 20 t.

$N$  = power in HP.

$G$  = axle load in kg.

$b$  = acceleration in  $\text{m/s}^2$ .

$V$  = speed km/h.

<sup>(1)</sup> HASSELGRUBER: « Zur Berechnung der Wärmespannungen in der Bremsstrommeln für Kraftfahrzeuge beim Haltbremsvorgang » (The calculation of the thermic stresses in brake drums on motor vehicles when braking to a stop). « ATZ », 54, 1952, No. 2.

HASSELGRUBER: « Temperaturberechnungen für mechanische Reibungskupplungen » (Calculations of temperature for mechanical friction couplings). « Vieweg », ed. 1959.

The case of an unequal flow of the heat, in the direction of the brake shoe and of the wheel, which occurs here, was studied by a similar method by Ehlers of the Knorr Brake Co. at Munich.

which were recognised as being of sufficient accuracy as they agree very closely with measures made on the test bench for 10 t (right hand group of curves); the masses of the test bench were not great enough for 20 t.

The criterion of the powers that can be supported by disc brakes with synthetic linings and wheel brakes with synthetic brake blocks is the superficial temperature which such materials will stand. At the present time these are, according to the quality of the line, 360 to 400° for prolonged stresses and about 450° for stresses of short duration, such as braking to a stop. The 640 mm disc brake is still below 400° for an axle load of 10 t, even when braking at 250 km/h; in the case of a 20 t axle load, the danger zone is only reached at 200 km. These consequently will be the limiting speeds.

The plastic brake blocks acting on the tyre which were studied (left hand side group of curves) gave less satisfactory results; the material used for the blocks had a particularly low thermic conductivity (without steel wool nor any metal addition). Nevertheless, for 10 t the maximum temperature at 250 km/h is still below 450°; for 20 t and from 150 km/h it is only 400°.

As was expected, the curves for cast iron brake shoes which are good conductors of heat are much lower. Even the 20 t axle only gives a maximum of 500° at 250 km/h.

Shoes made of synthetic materials will behave in the same way if the material has more or less similar coefficients of penetration of the heat, such as for example shoes made of calcined materials.

If corresponding calculations are made for a « small » <sup>(2)</sup> wheel of 600 mm (centre group of curves) it will be seen that the 10 t axle

<sup>(2)</sup> According to the researches of PRELLER and EHLERS, see BODEY: « Über die Belastbarkeit von klotzgebremsten kleinen Eisenbahn-rädern mit aufgeschrumpften Radreifen » (On the admissible load on small wheels with pressed on tyres braked by means of brake blocks). « Z. Leichtbau d. Verk. Fahrz. », 8, 1959, No. 6. The admissible braking load for a 600 mm diameter wheel is about 60 % of that of a standard 1000 mm wheel.

braked by cast iron shoes only has a temperature of 400° when braked to a stop from 250 km/h, but the shoe made of synthetic materials containing very little iron would only be suitable for speeds of up to 175 km/h because the temperature limit for this shoe

are naturally a little higher, because the friction surface and volume of accumulation of the heat are less.

But in the case of brake shoes coming up against wheels with pressed on tyres, the temperature of the surface of the wheel is

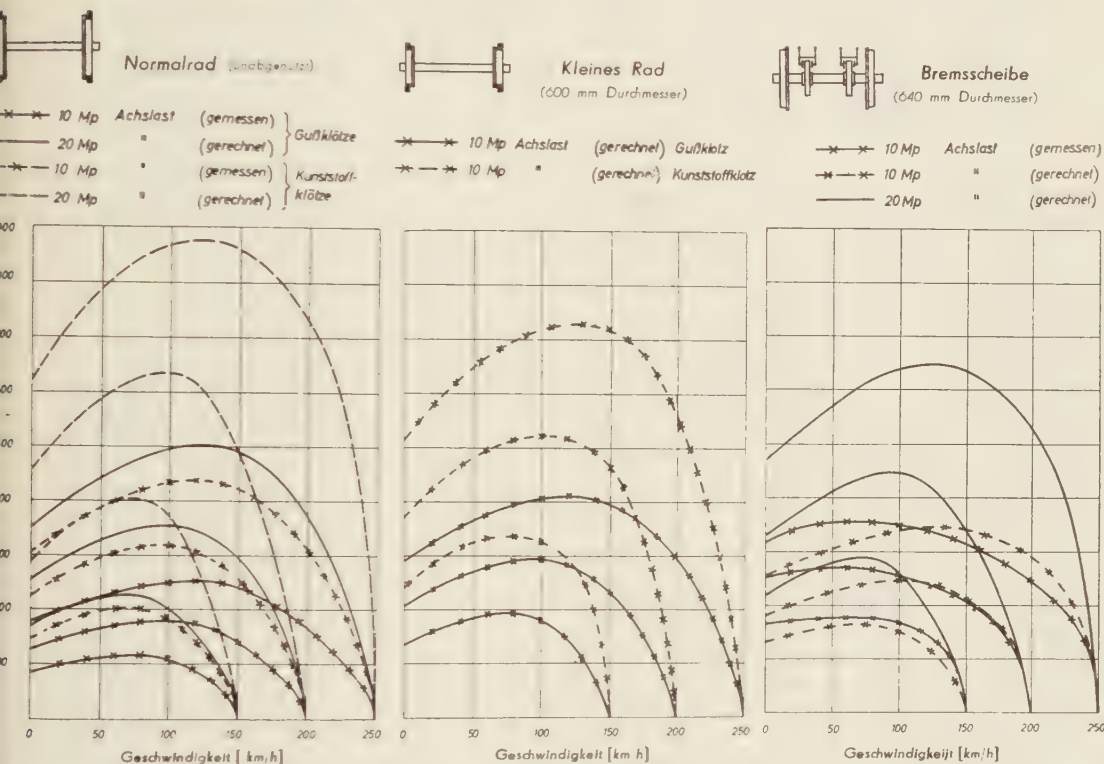


Fig. 4. — Variation in the temperature during braking to a stop at  $b = 1.2 \text{ m/s}^2$  and at 150, 200 and 250 km/h in railway wheels (measured 3 mm below the running surface) and in brake discs (measured on the friction surface) for axle loads of 10 and 20 t. Wind from running not taken into account.

N. B. — Normalrad = standard wheel. — Unabgenutzt = no wear. — Kleines Rad = small wheel. — Bremsscheibe = brake disc. — Durchmesser = diameter. — Achslast = axle load. — Gemessen = measured. — Gerechnet = calculated. — Gußklötze = cast iron blocks. — Kunststoffklötze = synthetic blocks. — Geschwindigkeit = speed.

is only 450°. For 20 t axles, the small wheel, which is being much discussed from the point of view of increasing the volume of the body, reducing the non-suspended masses and the low assembly height, would appear to be quite out of the picture.

With worn tyres, the peak temperatures

not the sole criterion of the braking power which they can absorb: the loosening of the tyres as a result of the braking heat penetrating into them also has to be taken into account. In braking to a stop from 250 km/h on the test bench with a 10 t axle load, this has never been known to occur.

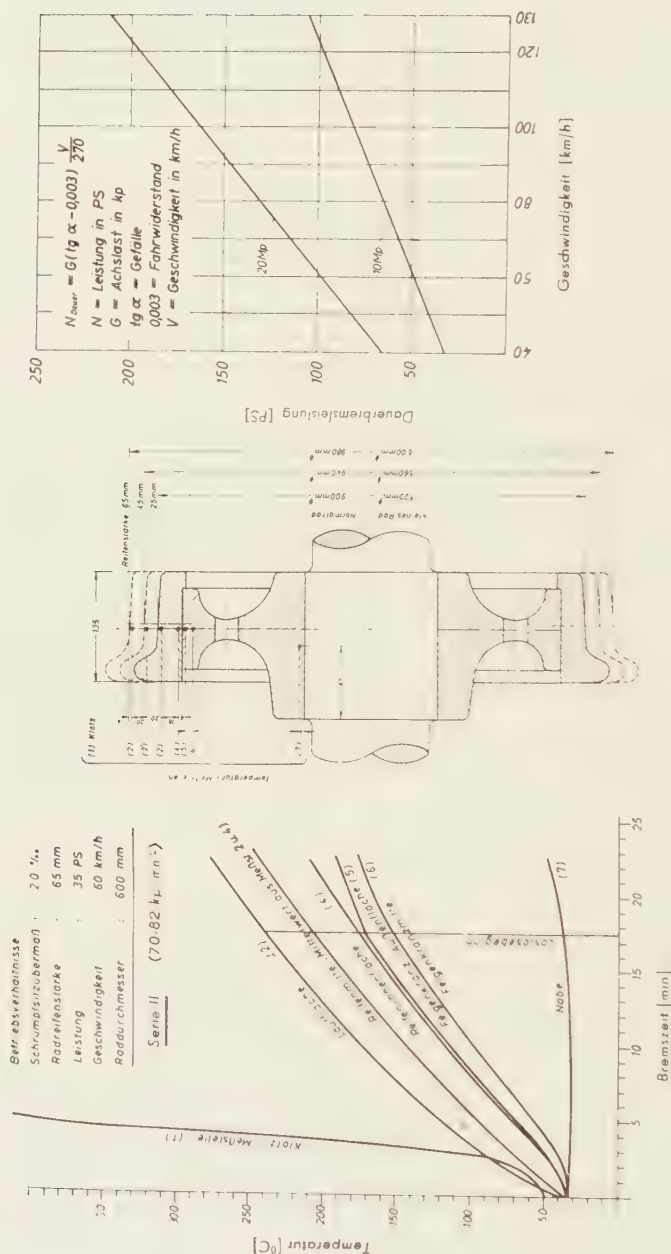


Fig. 5. — Example of the variation of the temperature at different measuring points on a « small » wheel until the tyre begins to get loose during prolonged braking. Influence of wind due to running not taken into account.

N. B. — Bremszeit = braking time. — Auflösbeg. = beginning of loosening. — Nabe hub. — Klotz, Meßstelle 1 = block, measuring point 1. — Lauffläche = running surface. — Reifenmitte... (2 u. 4) = middle of the tyre (average of measuring points 2 and 4). — Reifinnenfläche = inside surface of tyre. — Felgenkranz-Außenfläche = exterior surface of the tread. — Felgenkranzmitte = middle of the tread. — Betriebsverhältnisse = conditions of working. — Schumpfsitzübermaß = brake application. — Radreifenstärke = thickness of tyre. — Leistung = power. — Geschwindigkeit = speed. — Raddurchmesser = diameter of wheel.

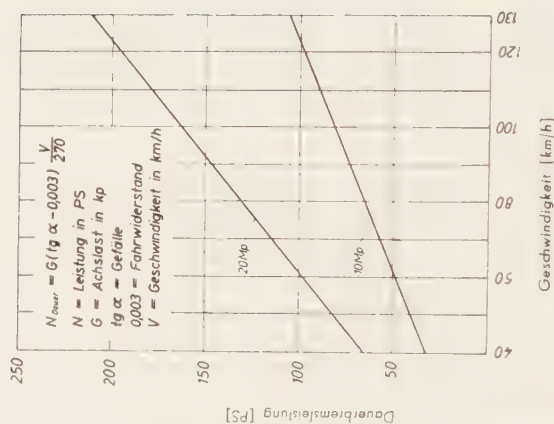


Fig. 6. — Continuous braking power per axle for a constant running speed down a gradient of 25 ‰; axle loads of 10 and 20 t.

N. B. — Temperatur-Messstellen = points of measurement of temperature. — Reifenstärke = thickness of tyre. — Kleines Rad wheel. — Dauerbremsleistung = continuous braking power. — Leistung in PS = power in HP. — Achslast in kP = axle load in kg. — Gefälle = down gradient. — Fahrwiderstand = resistance to forward running. — Geschwindigkeit in km/h = speed in km/h.

which means that there is absolutely no risk in the case of passenger coaches even at 250 km/h. According to EHLERS' calculations <sup>(2)</sup>, this risk does not occur even with minimum thicknesses of tyres (35 mm) for passenger coaches. In the case of 20 t axle loads, on the contrary, the thermic stressing is twice as great. Here EHLERS' calculation gives approximately the following results: with tyres 25 mm thick, the admissible speed for braking to a stop at about 1.2 m/s<sup>2</sup> with an application of 1.5 ‰ on the tyre is about 145 km/h, and with an application of 2 ‰ about 170 km/h. 35 mm thick tyres allow of about 170 km/h with 1.5 ‰ and 195 km/h with 2 ‰. With new tyres a speed of 245 km/h with 1.5 ‰ and 295 km/h with 2 ‰ is possible without the tyres becoming loosened. The calculations moreover have a considerable safety margin, because the favourable effects of the volume of the tyre under the flange has not been taken into account. To facilitate the calculations, the tyre has been taken as being a cylinder of the width of the brake block. Nor has the favourable effect of the wind set up by running been taken into account. With monoblock wheels, this criterion of the type disappears and is replaced by the superficial temperature alone. Under certain conditions, braking to a stop with maximum deceleration from 250 km/h is therefore also possible in the case of 20 t axle loads.

It is easy to determine the moment at which the tyre becomes loosened on the test bench owing to the fact that increases in the temperature on either side of the joint of separation begin to diverge (fig. 5) <sup>(3)</sup>. The other temperature curves show what happens at other measurement points on the wheel.

## 2.6. Prolonged braking.

Things are quite different in the case of prolonged braking on long, steep gradients

where the braking power is much less but acts for a much longer time on the tyres. Figure 6 shows the continuous powers for 10 and 20 t axle loads as a function of the constant running speed down gradients of 25 ‰; this is about the longest down gradient in Europe, about 20 km long, in the case of international traffic. The extended scale of speeds has been purposely limited in this case to 130 km/h because the long downhill runs also have many bends, so that they cannot be run over at the same speeds as the level lines.

The critical load point is reached after a different braking period at the various constant downhill speeds according to the axle load, the type of brake (disc or block brake) and (in the case of block brake) according to the thickness of the tyre, its tensile strength and the shrinkage value (figure 7). With the standard wheel, with a normal shrinkage-allowance (group of curves on the left) and a 10 t axle load, the critical time at a sustained speed of 130 km/h is reached after 17 minutes running, if the tyres are 65 mm thick, and after 11 minutes if they are only 45 mm thick. Wheels with tyres less than 35 mm thick can no longer be considered for fast vehicles. With a 20 t axle load, the admissible braking time at 130 km/h falls to 5 minutes (65 mm thick tyres). The 640 mm brake disc, the maximum dimension used with axles with standard wheels (I vehicle gauge) is equivalent from the point of view of admissible duration of braking to an axle with new tyres and is naturally independent of the wear of the tyres.

In each case, when we know the admissible braking time, we can determine the corresponding admissible braking times for any 25 ‰ downhill run. For this purpose, we have also shown in the graphs of figure 7 the curves of the running time for down gradients 20, 15, 10, 5 and 1 km long, the admissible situations with these lengths of down gradients being those lying above the curve of the journey times. With a 10 t axle load, for example, tyres only 25 mm thick, and a down gradient 20 km long, speeds of more than 90 km/h would not be admissible. Passenger coaches, whose tyres are not less

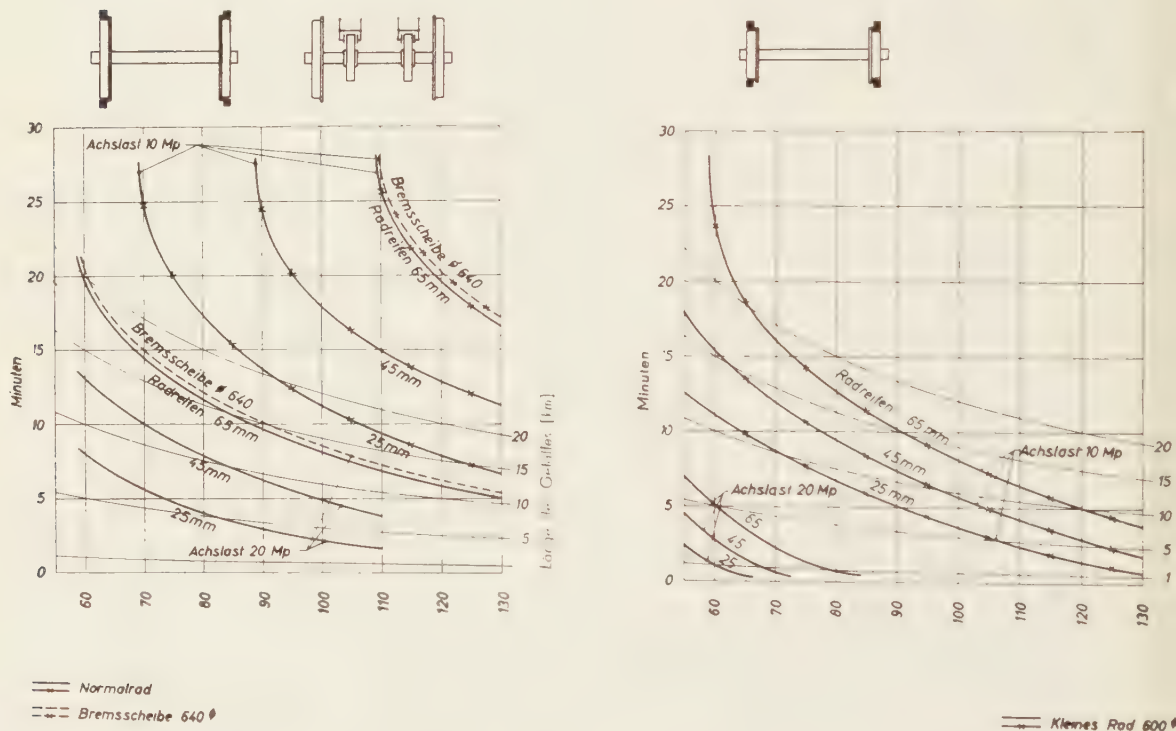
<sup>(2)</sup> See footnote on p. 506.

<sup>(3)</sup> BODEY: « Über die Belastbarkeit von klotzgebremsten kleinen Eisenbahnradern mit aufgeschrumpften Radreifen » (On the admissible braking effort for small wheels with pressed on tyres braked by means of brake blocks). « Z. Leichtbau d. Verk. Fahrz. », 8, 1959, No. 6.

than 45 mm thick, could run at more than 130 km/h. On the other hand, wagons with a 20 t axle load could not run down this 20 km long gradient except with new tyres of 65 mm at a maximum speed of 60 km/h, and with worn tyres, at a much lower speed. A 10 km long down gradient in the case of a 20 t axle load would have a limiting speed of 80 km with 45 mm thick tyres. The corresponding facts for brake discs (diameter 640 mm) and the "small" 600 mm wheel can be obtained in the same way.

With this latter a 10 km long down gradient could only be run down at 100 km/h at the maximum with tyres worn to 45 mm and an axle load of 10 t.

It must therefore be concluded that in the case of a goods train running down the gradients in the Alps at more than 60 km/h, the tyres must become loosened in the case of axle loads of 20 t, even when the tyres are new. It is a fact that on these long down gradients numerous cases of the tyres becoming loose have been observed, and there are



Downhill speed in km/h on a gradient of 25 ‰.

Fig. 7. — The critical moment in prolonged braking.

a) Block brakes: loosening of the tyre;

b) Disc brakes: temperature of disc 400° C.

Limiting speeds as a function of the length of the down run. Influence of wind due to running not taken into account.

N. B. — Normalrad = standard wheel. — Bremsscheibe = brake disc. — Kleines Rad = small wheel. — Achslast = axle load. — Bremsscheibe = brake disc. — Radreifen = tyre. — Länge... in km = length of the down gradient in km.

sure to be many more such cases, because many of them tighten up again before the train stops and the tyres are checked with the hammer. If in practice such « running with loose tyres » leads to very few incidents, this is probably because the loosened tyre rarely gets out of place on the tread, because it undergoes an elastic deformation which presses it down on the tread at the point of contact between the wheel and the rail under the action of the load on the wheel, as well as under the brake blocks under the action of the efforts exerted by these latter, and because the braking effort exercised by the blocks in the direction of the periphery of the tyre is transmitted directly to the rail. On the test bench, the situation is quite different; the loosened tyre can easily get out of place because there is no « rail ».

The observations made on the test bench and the conclusions derived therefrom would be quite frightening to the operator were there not a whole series of favourable influences:

- 1) down gradients of 25 ‰ are rare;
- 2) only in a few cases are they also of any length (Alps, Black Forest, Thuringer Wald);
- 3) it is rare for the gradient to be uniform throughout;
- 4) they are usually sinuous and running over them is difficult;
- 5) the measures made on the bench have been made without any wind due to running.

## 2.7. Influence of the wind due to running.

The importance of this influence is seen from figure 8 (<sup>4</sup>), which shows the temperature increase as a function of the time in a brake disc subjected to heavy stress (diameter only 460 mm and 33.5 HP!), the temperature of which at a constant speed of 50 km/h only rises to 370° with wind and

600° without wind respectively. The speed of the air was produced on the test bench by means of a fan. Unfortunately, for aerodynamic reasons, it is precisely on fast vehicles that the wind due to running is diverted by means of petticoats and all sorts of installations. It is precisely the opposite of what should be done, and the fresh air should be allowed to reach the discs and the wheels, at least when braking is taking place. Fans with which the engines, the transformer and diesels are fitted are not allowed in the case of the brake which is treated as a poor relation. Fresh air conduits which might only open during braking, or fans which would form very important « safety air conditioning installations » have often been suggested for many years.

## 2.8. Accumulative and mixed braking

Moreover, there are cases which lead to still higher thermic stresses than running

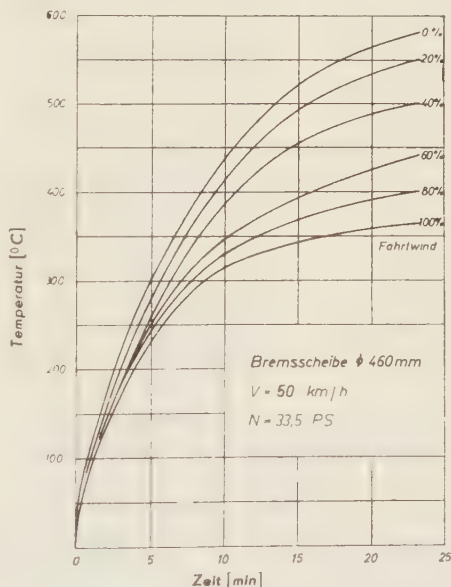


Fig. 8. — Rise in the temperature of the disc during prolonged braking at constant power as a function of the running wind.

N. B. — Bremsscheibe = brake disc. — Zeit = time. — Fahrtwind = running wind.

(<sup>4</sup>) Taken from the M.S. of EHLERS' thesis: « Die Energieumwandlung bei der Scheibenbremse » (The conversion of the energy in the disc brake).

down gradients, for example on metropolitan lines where numerous brakings to a stop from high speed follow one another very rapidly, so that the brakes do not have time to cool sufficiently between whiles. Figure 9 corresponds to an 18 t axle load with a 640 mm disc per wheel with 20 brakings to a stop from 120 km/h with a deceleration of  $0.7 \text{ m/s}^2$  during 50 minutes. From

Figure 10 represents an interesting analogous test on the bench corresponding to a faithful imitation of a Swiss tramway line, in conjunction with a great difference in altitude.

### 2.9. Conclusions.

The above considerations show, however, that on the whole the mechanical part of

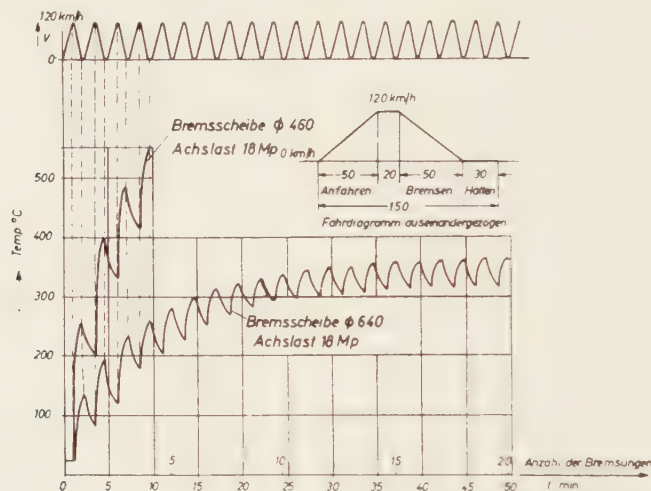


Fig. 9. — Variation in the temperature of a brake disc in the case of repeated fast brakings at  $b = 0.7 \text{ m/s}^2$ . Imitation of a run on the level with stops close together and a maximum speed of 120 km/h. 20 brakings in 50 min. Influence of wind due to running not taken into account.

N. B. — Anzahl der Bremsungen = number of brakings. — Bremscheibe = brake disc. — Achslast = axle load. — Anfahren = starting up. — Bremsen = braking. — Halten = stop. — Fahrtdiagramm... = graph of spread out run.

starting to 120 km/h : 50 s; running at a constant speed of 120 km/h : 20 s; braking : 50 s; stop : 30 s.

This case resembles the service worked by the ET 30 electric rail motor coach in the fast services in the Ruhr. The temperature rapidly accumulates from one braking to another, and a disc which is only 460 mm in diameter has its capacity exhausted by the second braking, whilst a disc of 640 mm diameter keeps at a temperature of less than 400°.

the brake, which exhausts the energy, still has considerable reserves for an increase in the speed, especially in the case of running on the level, but also on down gradients, provided the speed is fixed not only according to the profile of the line, but also the length of the down gradient. But it is certain that the 20 t axle of fast motor units and locomotives is the most difficult problem, if not mitigated in the future by adding engine brakes.

As regards the brakes acting on the

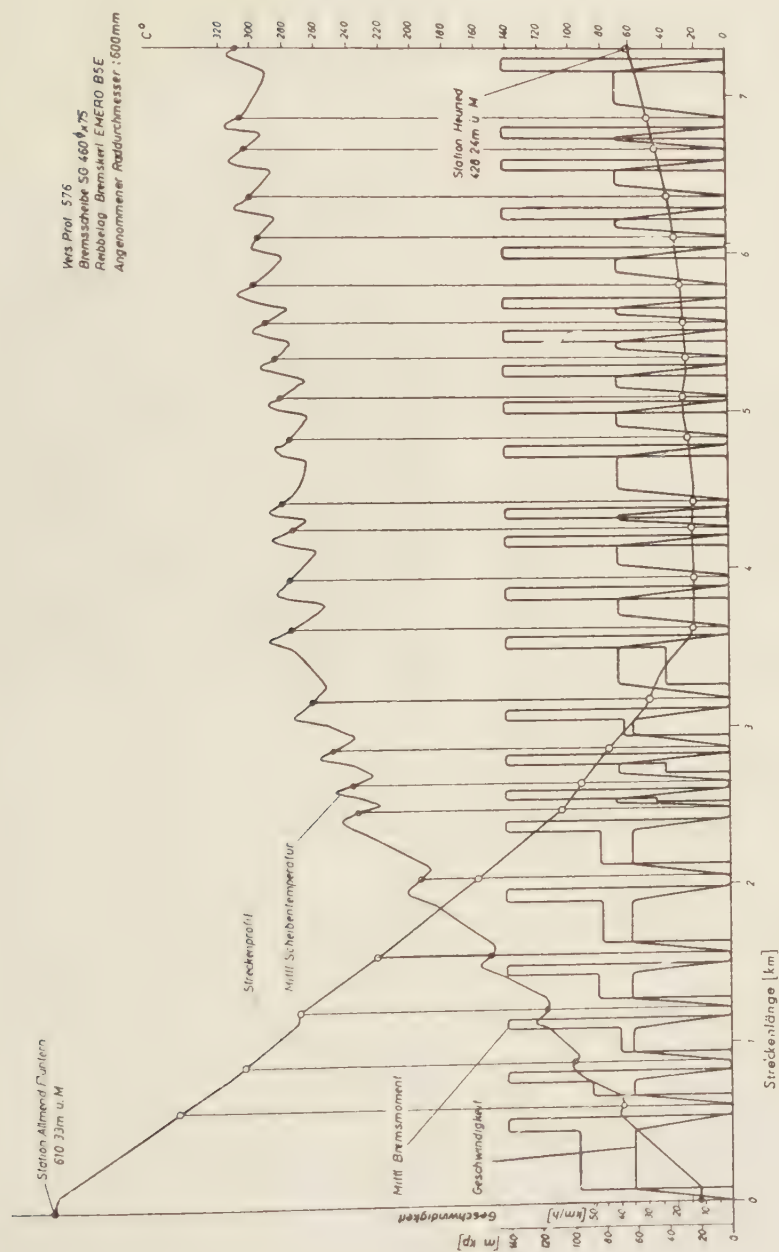


Fig. 10. Variation of the temperature during a downhill run and a run on the level with stops at short intervals.  
Influence of the wind due to running not taken into account.

N. B. — Geschwindigkeit = speed. — Streckenlänge = length of the line. — Mittl. Bremsmoment = average braking moment. — Mittl. Scheibentemperatur = average temperature of the disc. — Brems Scheibe = brake disc. — Vers. Prot. = report of the test. — Reibbelag = friction lining. — Angenommener Raddurchmesser = supposed diameter of wheel.

wheels, the monoblock wheel can do away with the problem of the loosening of the tyre, substituting for it in the case of the running surface the notion of the admissible superficial temperature, which, as is known, also has its limits due to the tensile strength at high temperatures and the modifications in structure.

The brake disc thus becomes one of the essential elements in increasing the speed, because it lightens the load on the wheels as regards braking.

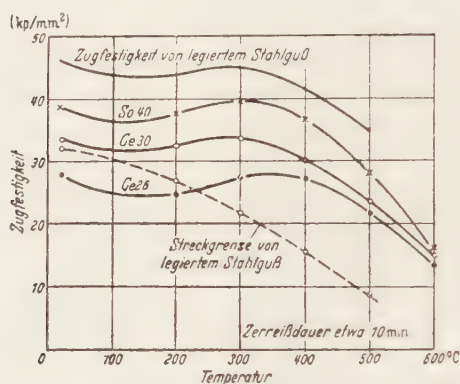


Fig. 11. — Resistance as a function of the temperature of the cast steel alloy and the variations in high quality cast iron (R. Mailänder and H. Jungbluth, according to E. PIWOWARSKY: « Cast Iron ». Publisher Springer, 1951, fig. 587.)

N. B. — Zugfestigkeit = resistance to traction. — Zugfestigkeit... Stahlguß = resistance to traction of cast steel alloy. — Streckgrenze... = elastic limit of cast steel alloy. — Zerreißdauer etwa... = breaking time about 10 min.

### 3. Increasing the power of the brake.

#### 3.1. Improved brake discs.

The brake disc itself has already undergone an evolution which has increased its power. The classic discs of cast steel often showed, after short period of overload, superficial damage which began as burns and led progressively to the formation of microfissures, deposits of welded metal in the form of beads, and wear of the disc and the

lining. Such damage was caused by local heating in the thin layer in which the conversion of the energy takes place under serious shearing stresses.

This overheating, due to an uneven distribution of the load, might be several hundred degrees above the temperature measured by the thermo-electric cell, as is proved by the formation of sparks, welding phenomenon, and alterations in structure. But with such an increase in the temperature, the elastic limit is very considerably reduced in these surface elements, and displacements of material occur with destruction of the texture. Such local temperatures also destroy the temper and the finish of the surface. In this connection grey iron is much more stable, its elastic limit and breaking strength are practically identical, and their variation as a function of the temperature (fig. 11) is so favourable that even GG 26 cast iron is better than steel at 300°. To this high resistance to plastic deformation we must add the well known stability of cast iron in the face of oxydising and disoxydising factors and those capable of modifying the texture, the small length of the particles removed by abrasion and their small propensity to weld together; finally the specific heat and consequently the capacity to accumulate heat is higher in the case of cast iron than steel in the proportion of 0.11 to 0.18/0.19.

But the classic type of brake disc cannot purely and simply be made of cast iron. The heat due to braking in the rim of the friction surface by flowing through the hub could reduce the necessary shrinkage, which in the case of cast iron must necessarily be much lower than in the case of cast steel. But in addition, the differences in temperature between the friction rim and the hub would give rise to stresses which cast iron spokes cannot stand; they would break — this has been confirmed by tests — at very low braking power. Reinforcing the spokes does no good, if only because it prevents the internal ventilation of the disc.

The form shown in fig. 12 is one solution in which the hub is made of cast steel and the braking rim — in one or several pieces — is made of grey iron. These two com-

ponents are connected together by removable spokes made of strong, elastic steel tube (which can be seen at the top of the figure). The braking grey iron rim can expand freely over a large number of these spokes. The flux of heat in the direction of the hub at an increasing temperature is

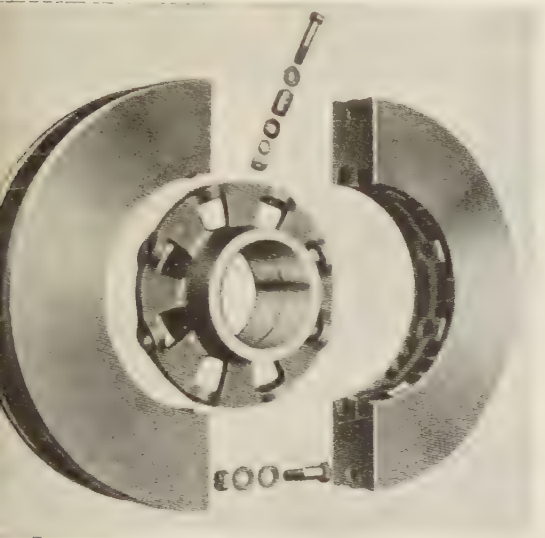


Fig. 12. — Cast iron brake disc with free expansion on steel hub. Type with 2 piece friction rim. Above: tubular spoke with elastic shrinkage; below: bolt for assembling the two halves of the rim.

further prevented by a wider gap. The type with a rim in *several parts* makes it possible to exchange parts without dismounting the wheels and the hub which are keyed on the axle.

The centrifugal forces of the two halves are absorbed by the elastic steel tube but not by the assembly bolts which simply secure the two halves together.

These brake discs keep cooler and they can be used at higher powers and show less wear. Measurements taken on the test bench and over long periods of observation in service have shown that the wear is only half that of steel discs. With these discs, no damage is done if they run red hot for

several hours if suitable linings are used, but these unfortunately wear rather more rapidly. Figure 13 shows that with a lining whose resistance to the temperature only exceeds that of the linings currently used at present by about 100°, it is possible to get a power of 90 HP per disc. This makes it possible only to use one disc per axle instead of two in certain cases, as practical tests have already shown.

### 3.2. Combined brake on tyres and discs.

With the introduction of « small wheels », the space available inside the vehicle loading gauge (fig. 14) became so small that it is now absolutely impossible to fit the brake discs on the axle centre, so that once again it was impossible to consider anything but a simple brake acting on the tyres. In this case, it is however possible to fit the brake discs inside the wheel, and it is perhaps interesting in this case to brake at the same time as these discs, the tyres — each component within its admissible capacity — but on their sides and not on their running surface. A wheel of this kind, made in the form of a ventilated monoblock wheel — the system might later on be adapted to the larger standard wheel — doubtless represents the optimum solution from the thermic point of view. It is only necessary to pay special attention to the heating of the axle boxes and grease as a result of the braking, heating which is for the time being

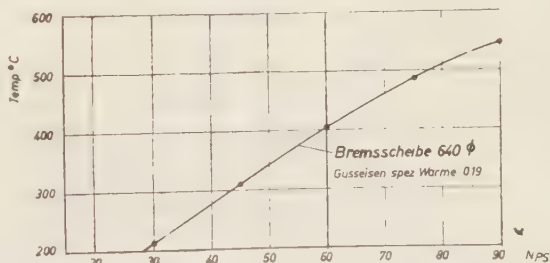


Fig. 13. — Final temperature of a brake disc after 20 min prolonged braking as a function of the braking power at a constant speed of 60 km/h, without taking the influence of the wind due to running into account.

N. B. — Bremsscheibe = brake disc. —  
Spez. Wärme = specific heat.

limited to 100%. It would appear to be interesting to study the axles from this point of view.

If we get rid of conventional ideas, it can be appreciated that the brakes on the wheel, the disc brakes and possibly combinations of the two systems will completely meet future requirements; they could never have to supply more power than the limit of power dictated by the coefficient of adhesion between rail and wheel.

brake, such as rheostatic brakes, regenerative brakes, electric or hydraulic eddy current brakes, are connected with the constructional elements wheel and rail. They are solely of thermic interest or for saving power and wear. They do not reduce the braking distances.

### 3.4. Magnetic rail brakes.

The electro-magnetic rail brakes are, as the curves of figure 1 show, very effective

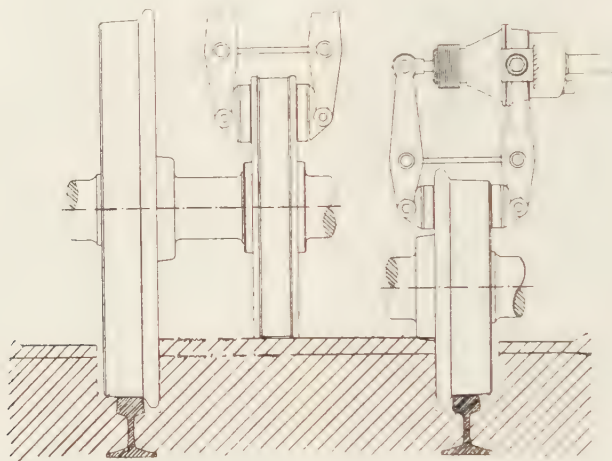


Fig. 14. — Standard 1000 mm diameter wheel and « small wheel » of 600 mm diameter with worn tyres, within the vehicle loading gauge. Possibilities of fitting a brake disc.

### 3.3. Other means of deceleration.

Decelerations greater than the normal limit of adhesion can be obtained by increasing the adhesion by means of sanding (which is problematic at high speeds), or using materials with greater adhesion for the wheels, such as rubber and other synthetic materials (axle loads and ageing) and in theory also by magnetic devices to increase the adhesion. Apart from this, the only other additional decelerators are aerodynamic devices, for example « roughing up » the surface of the vehicle by causing artificial turbulence, in the case of highly perfected vehicles, reaction journals or again magnetic brakes on the rails. All the other types of

and well tried methods by means of which the total deceleration of complete trains can be increased to slightly over  $2 \text{ m/s}^2$ . Their effects have been studied up to 170/180 km/h. But above these speeds, we get very conclusive evidence from the point of view of the coefficient of friction of the now well known fact of the sliding of the brake blocks on the tyres; they cannot but be more favourable owing to the fact that the rail remains cold.

It is already proposed to control these brakes in such a way that they come into action gently and that the increase in the friction at low speeds, which is a feature of such brakes, can be corrected. In the case of high speeds, the only problem that re-

mains is the question of the points and crossings. This is a problem that will have to be dealt with in the future by the bogie designers: to design bogies which not only have good running qualities and good suspension, but also special layouts for the installation (not the fitting later on) and guiding along the track of the brake electro-

#### 4. Problems of pneumatic control of the brake.

##### 4.1. The control of the brakes.

From the point of view of the technique of control, all the problems concerning the isolated vehicle are solved in order to assure the utilisation of the coefficient of friction,

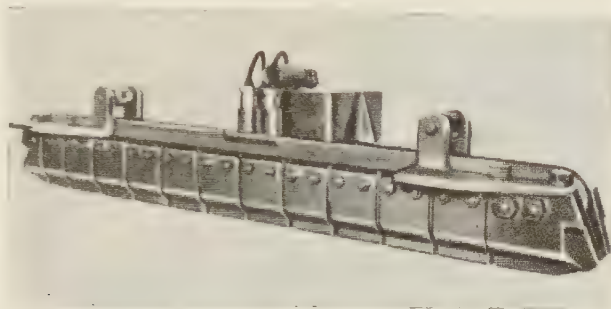


Fig. 15. — Articulated brake electro-magnet.

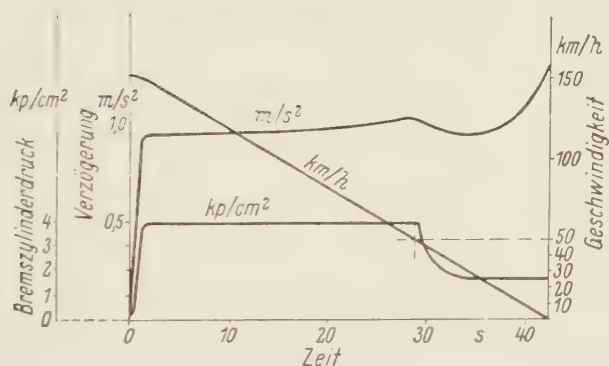


Fig. 16. — Variation of the pressure in the brake cylinder. Deceleration and speed during braking at 150 km/h with cast iron brake blocks.

N. B. — Bremszylinderdruck = pressure in the brake cylinder. — Verzögerung = deceleration. — Geschwindigkeit = speed.

magnets. Their suspension from the axle box supports and their lengthwise location in the space between the wheels would appear perfectly logical for this purpose with the use of disc brakes instead of blocks. Articulated brakes are particularly effective owing to the flexibility of adaptation of the different elements (fig. 15).

of the coefficient of adhesion and of the adhesion.

Compressed air brakes with grey iron blocks are influenced automatically by the brake pressure regulator from the axle box in such a way that they take into account the variation as a function of the speed of the coefficient of friction of the cast iron

blocks (fig. 16). A single reduction of the pressure in the brake cylinder at about 50 km/h is sufficient to maintain the deceleration more or less constant, because the block helps this by the deformation it undergoes whilst heating up. With blocks made

The anti-slip regulators make it possible to dimension the brakes without risk more or less according to the optimum coefficient of adhesion. They protect each axle (fig. 17) by automatically reducing the braking effort for a short instant the moment a wheel tends

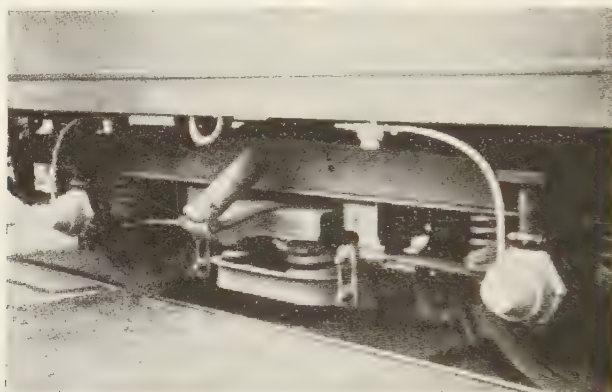


Fig. 17. — Anti-skid regulator on the bogie of a coach equipped with the KE-GPR brake.

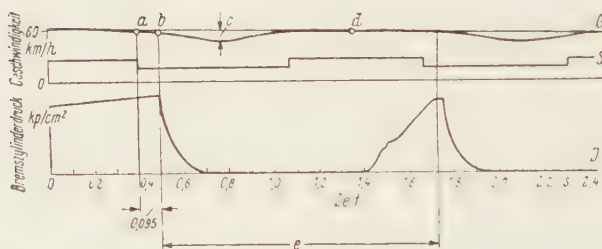


Fig. 18. — Variation in the peripheral speed of an axle fitted with an anti-skid device during slip caused on two occasions, for a deceleration of  $0.91 \text{ m/s}^2$  because of oil on the rail.

- G. Variation in the speed.
- S. Zones of intervention of anti-skid regulator.
- D. Pressure in the brake cylinder.
- a. Point at which the anti-skid regulator is released.
- b. Point at which the brake comes off.
- c. Loss of speed in the skidding axle 13.3 km/h.
- d. Absolute speed 57 km/h.
- e. Time braking is acting.

N. B. — Zeit = time. — Geschwindigkeit = speed. —  
Bremszylinderdruck = pressure in the brake cylinder.

of synthetic materials and brakes with linings, such regulation is unnecessary, because their coefficient of friction is more or less independent of the speed <sup>(5)</sup>.

<sup>(5)</sup> MÖLLER : « Neue Druckluftbremse für sehr schnelle Eisenbahnzüge » (New compressed air brake for very fast trains). « Z. VDI. », 99, 1957, No. 12.

to skid as a result of local fluctuations in the coefficient of adhesion (oil, leaves, etc.). This automatic operation takes place so quickly (fig. 18) that the braking distance of long, fast trains was hardly increased at all when a trial braking section was covered with greasy soap over a long length in order to make all the axles exceed the limit of the coefficient of adhesion (fig. 19) <sup>(6)</sup>.

Modern compressed air brakes also adapt themselves to the load conditions conti-

nuously and automatically by means of the pressures in the brake cylinders, when circumstances make this necessary.

#### 4.2. Long, heavy trains.

With modern compressed air brakes, control operations do not raise any problems as regards braking and taking off the brakes, even in the case of long trains. Indirect action compressed air brakes make available with their reservoirs filled to 5 kg/cm<sup>2</sup> in the released condition, a sufficient reserve of power on each vehicle, and they can be used with very precise regulation, with practically no loss of time. These brakes with their automatic feed are inexhaustable, even on long, difficult downhill runs <sup>(7)</sup>. The speed of propagation, which is nearly 300 m/s, has been taken very close to the theoretical limit (330 m/s) and owing to the acceleration by means of acceleration chambers, has been made independent of the length of the train, so that not only the long European trains of 1 000 to 1 200 m, but even the long American trains of more than 2 000 m are perfectly braked. During rapid brakings, the pressure can be reduced at every part of the train by bleeding devices, so quickly that the braking diagram obtained at the end of the train is the same as that for the first wagon <sup>(8)</sup>. Figure 20 explains the operation in principle for a 500 m long train. This representation can easily be extended to longer trains. If these speeds of propagation should really become insufficient, there is also the possibility of electric control.

Unlike the braking, however, the taking off of the brakes on very long and heavy trains by means of moderate brakes is more difficult because owing to the required inex-

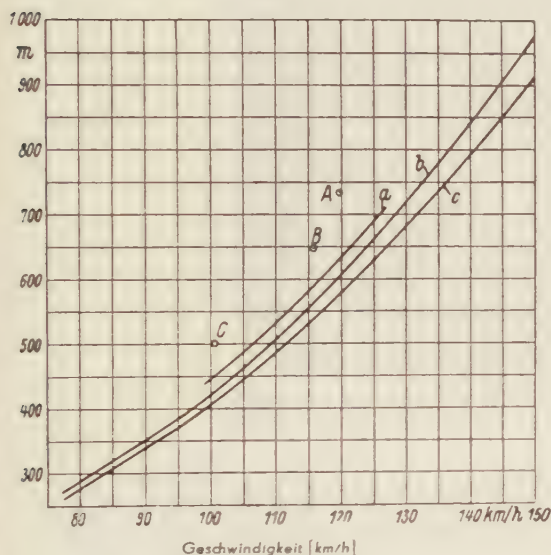


Fig. 19. — Braking length of a fast train equipped with KE-GPR brake. Weight of train: 688 t.

- a. Without rapid braking accelerator and without locomotive brake.
- b. Without rapid braking accelerator and with locomotive brake.
- c. With rapid braking accelerator and locomotive brake.
- A B C. Points of measurement of runs as under a, but the rails had been greased with greasy soap so that the anti-skid regulators of all the axles had to come into action.

N. B. — Bremsweg = braking distance. —  
Geschwindigkeit = speed.

<sup>(6)</sup> MÖLLER: « Gleitschutz, ein Weg zur Hochleistungsbremse » (Protection against skidding, a means of obtaining a very powerful brake). « Glas. Ann. », 65, 1941, No. 3.

<sup>(7)</sup> MÖLLER: « Die neue Eisenbahndruckluftbremse mit dem KE-Einheitsventil » (The new compressed air brake with standardised KE distributor). « Z. VDI. », 96, 1954, No. 11 and No. 12.

<sup>(8)</sup> MÖLLER: « Gleitschutz, ein Weg zur Eisenbahndruckluftbremse » (Critical considerations on the compressed air brake for railways). « Glas. Ann. », 80, 1956, No. 11.

haustability, the quantity of air used for braking on each coach must be replaced as the operation of taking off the brakes proceeds. The taking off of the brakes on such trains is made difficult by the large quantities of air which have to be moved in a very short time in the main air conduit.

in the time taken to take off the brakes and at the same time the accelerating influence of the first recharge i.e. the momentary use of a higher pressure than the normal pressure of  $5 \text{ kg/cm}^2$ . The time taken to take off the brake in the case of fairly heavy trains can be reduced in this way, after com-

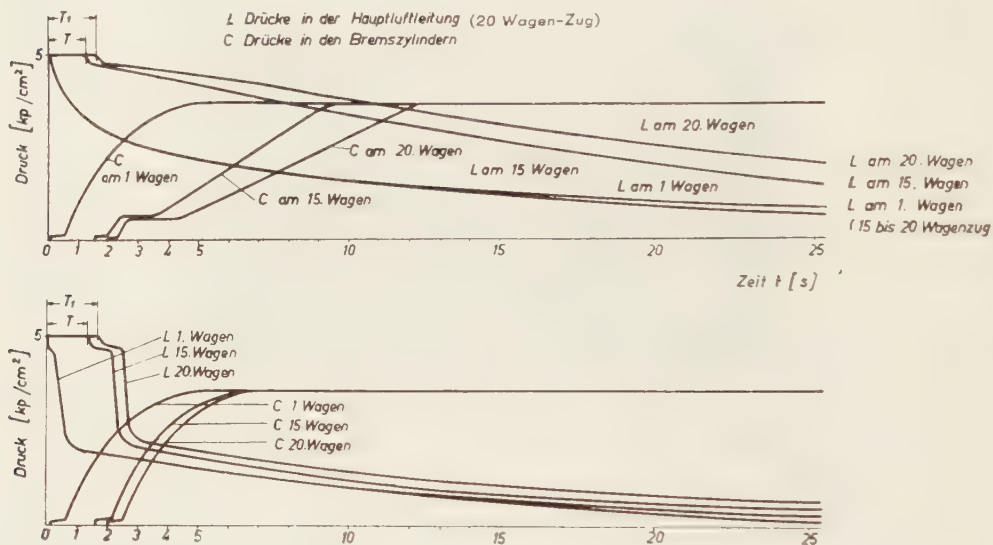


Fig. 20. — Pressure in the main brake pipe and in the brake cylinder during rapid braking for different coaches of an express train consisting of 20 four axled coaches without rapid braking accelerator (above), and with rapid braking accelerator (below). Total length: 517 m.

N. B. — Druck = pressure. — Drücke in der Hauptleitung = pressures in the main pipe. — Drücke in den Bremszylindern = pressures in the brake cylinders. — am 1. Wagen = on the first coach. — Zeit = time. — 15 bis 20 Wagenzug = train of 15 to 20 coaches.

The possibilities of improving these operations of taking off the brakes have been studied on a brake test bench (fig. 21) whose dimensions make it unique in Europe. It represents the original brakes of a railway train 2 300 m long.

The following methods can be considered:

1) reduction of the resistance in the brake conduit by replacing the one inch conduit currently used in Europe by one of  $1 \frac{1}{4}$ " and over. Figure 22 shows, for a 7 000 t train, which consequently represents a multiple of those now running, the radical reductions

plete braking, to 60 s or less. In fact, it is only the European railways who still retain inch conduits. New wagons should be built today with  $1 \frac{1}{4}$ " conduits: the air brake hoses can be kept as they have large dimensions, and give only the minimum restriction in relation to the resistances of long conduits.

2) dephasing in the increased time interval between brakes being taken off and the refilling of the reservoirs on each vehicle, for example by subdividing these reservoirs into sections some of which are filled first and some later on, and by calculating ratio-

nally the starting and acceleration times after a stop up to a certain running speed. The results correspond more or less to those obtained with increasing the diameter of the main conduit to 1 1/4". But the method involves concessions from the point of view of design or methods used.

3) measures intended to economise on the air used. We are thinking here of the re-

bles experienced in taking the brakes off, even in the case of the longest and heaviest trains, would however be the total separation of the brake control and the transport of air. For this purpose, we could use either the existing main brake pipe, if necessary increased to 1 1/4", solely for refilling and supplying, at a constant pressure of 5 kg/cm<sup>2</sup> and add the electro-pneumatic controls al-



Fig. 21. — Test bench for compressed air brakes for trains up to 2 300 m long with loads of about 15 000 t.

duction in the play of the brake blocks, the flexibility of the rigging, the suppression of slack, as well as separating the application and braking cylinders, or again of the advantages in the same direction of the unitary effect of the modern KE brake (?). However brake blocks of plastic materials are the beginning of a very drastic evolution. Their coefficient of friction is nearly double that of grey iron blocks. Their use will make it possible to reduce by half the present effort at the brake cylinder and consequently the amount of air needed. Blocks of plastic materials have not yet been fully perfected, but there is no need to be specially brave to believe in them. Disc brakes with synthetic linings are also a great step forward in the same direction and must be carefully followed.

4) the most radical remedy for the trou-

ready mentioned, or again provide a separate pipe for refilling beside the usual compressed air control pipe. This second pipe would already result in considerable advantages, even with the lengths of train used in Europe which would not be merely the reduction in the time taken for brakes off. It would make all the measures now used to assure inexhaustibility superfluous; it would allow of — especially if it had a pressure higher than 5 kg/cm<sup>2</sup> for example 10 kg/cm<sup>2</sup> — much higher pressures in the brake cylinders of the different vehicles (smaller brake cylinders and reservoirs) and very pleasing pneumatic braking to load even in the difficult cases of high and varying axle loads, which will certainly become an important consideration in the future. In the case of pneumatic suspensions, the pneumatic devices for closing the doors and

other compressed air controls, this second pipe would even be necessary, because one cannot take air from the control pipe. The reserve of high pressure air, by analogy with the braking accelerators, would allow of the installation of brake off accelerators of equally good design.

When we consider the simplicity of the addition involved by this second pipe com-

pared with the increase in power assured by it, it clearly should be stipulated under all circumstances and provided straight away if we want to adopt automatic couplings with centre buffer in Europe.

The results of measurements taken (fig. 23) show the time taken for brakes off in the case of brakes with two pipes for trains of as long as 2 300 m. It would then be possible to take the brakes off on trains of this length as rapidly as on the usual trains of today in Europe (about 1 000 m long), for which a maximum of 70 s is allowed using recharging for 20 to 30 seconds. The load of the trains has no influence on the technique of control, because the difference in the consumption of air for braking does not affect the control pipe.

It can therefore be seen that there are so many means of taking the brakes off on longer and heavier trains that it is difficult, even for the specialist, to select or combine together those most economical and suitable for the operating conditions of the railway under the most diverse conditions, without falling for the impossible.

There is no reason to think that the length of European trains will exceed 1 000 to 1 500 m as if they did, this would involve reconstruction of the passing tracks and marshalling yards. Nor is there the traffic to justify such long trains, and there might not even be in spite of a new increase in the density of the population. Before thinking of increasing the length of the trains, they should be speeded up or the weight increased by the use of four axled wagons. It is true that increasing the train loads would mean an increase in the volume of air needed for the compressed air brakes, which would have to be assured by the above mentioned methods. But all the same these future problems should not be considered solely from a European point of view, and still less from a national point of view. The railway is an international means of transport, not only because some wagons travel freely from one country to another but also on account of technical progress throughout the whole world in a much wider sense. In the vast regions of the Orient and Africa, the essential conditions for making up hea-

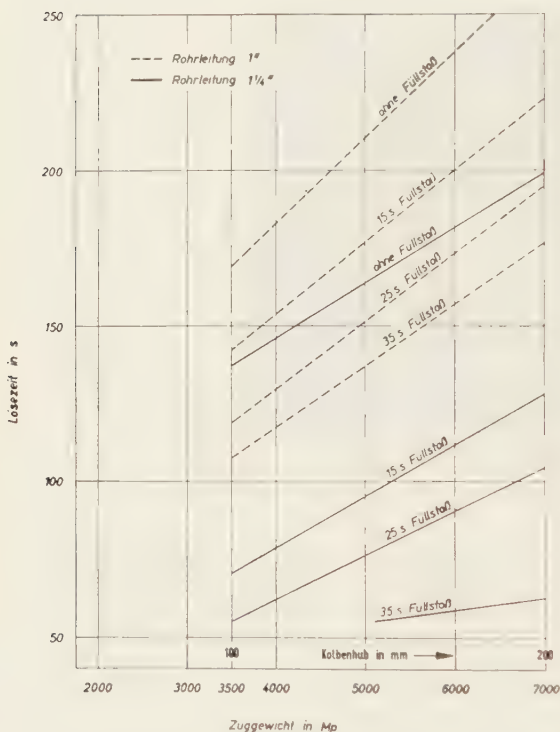


Fig. 22. — Time taken to release the brakes on heavy goods trains after a full application with 1" and 1 1/4" pipes (length of train: 1 000 m; braked at 100 %; 12" brake cylinders; pressure in the main reservoir: 10 kg/cm<sup>2</sup>). Measured without first recharging and with recharging of different durations.

N. B. — Zuggewicht in Mp = weight of train in t. — Lösezeit in s = time required to take off the brake in s. — Kolbenhub in mm = piston stroke in mm. — Rohrleitung = pipe... — Ohne Füllstoss = without first recharge. — 25 s Füllstoss = 25 s recharge.

vier and perhaps longer trains are more favourable, and there are iron mines which make up 10 000 and even 14 000 t trains.

### Résumé.

The increase in world population and the ever increasing mobility of the individual are not without influence upon the structure

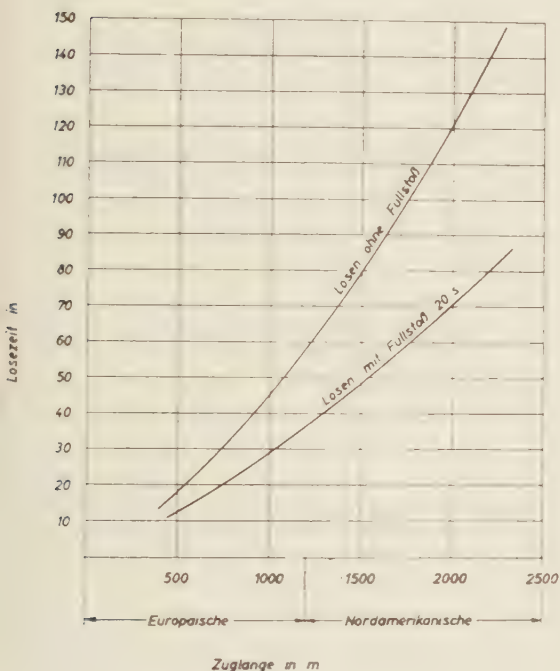


Fig. 23. — Time required to take off brakes on long trains with special recharging pipe after complete braking and without first recharge.

N. B. — Lösezeit = time for taking off brake. — Lösen ohne Füllstoss = releasing brakes without first recharge. — Lösen mit Füllstoss 20 s = taking off brake with 20 s first recharge. — Zuglänge in m = length of train in m. — Europäische = European trains. — Nordamerikanische = North American trains.

of transport. Whereas the roads are already restricting individual transport and aircraft are altering their sphere of activity towards the radius of action of reaction equipment, the railway has not yet made full use of all

its possibilities from the point of view of the length and weight of trains. The collective character of railway transport favours the establishment of certain laws for which the quality of the brake is one of the most important gauges. The better the brake, the faster the traffic can circulate, and the faster and heavier the trains can be.

Starting from practical experiences that have already been obtained, we have calculated first of all the possibility of increasing the speed up to 250 km/h on the level. This scale of speeds has been controlled metrologically for brakes with grey iron blocks and synthetic blocks applied to standard wheels of 1 000 mm diameter and to « small wheels » of 600 mm diameter, as well as for disc brakes, axles with 10 and 20 t loads, sharp and long down gradients, up to speeds of 130 km/h. It is possible to remain master of such speeds in the case of 10 t axle loads; the arrangements to be adopted in the case of 20 t loads are explained. The criteria are the superficial temperatures and the loosening of the tyres. The still more difficult case of fast runs with stops at close intervals on the level and runs on hilly lines with many stops have been studied on the test bench. The influence of the running wind is reported.

With disc brakes, the replacement of massive cast steel discs by discs fitted with cast iron friction crowns makes it possible to increase the admissible braking powers, the life and the economic efficiency.

After considering the limits of the braking power, the author deals with the coefficients of friction, of sliding and of adhesion and the practical way to make use of them with compressed air brakes controlled as a function of the speed, protected against skidding, and braking automatically as a function of the load, which leads to brakes at the limit of adhesion and their reinforcement by electro-magnetic brakes acting on the rail. These considerations complete the studies devoted to individual vehicles.

From the individual vehicle, the considerations of the future will go to the train itself. The speed of propagation of the braking, both electric and pneumatic, and its influence on service braking and sudden

braking are the subjects of a critical study. The main problem resides in the braking of long, heavy trains. For reasons of inexhaustability and of safety, automatic brakes which can be gradually released depend only on the degree to which their reservoirs are filled. The transport of these large amounts of air through the ordinary brake pipe consequently slows down the take off of the brakes and makes it more difficult to regulate the brakes as the train increases in length. It is shown that there are numerous ways of overcoming this defect: increasing the size of the pipe, dephasing between brakes off and the refilling, and artifices intended to economise the air used, amongst which brake blocks of synthetic materials are of particular importance. But the radi-

cal measure, which is to separate the control of the movement of the air by means of a special filling pipe, solves this problem so completely that it enables us to retain the mastery in the case of trains 2 500 m long with a 15 000 t load by means of brakes the take off of which can be regulated just as surely as in the case of the 1 000 m long 2 500 t trains of today.

From these studies, it may be concluded that the brake and its control by compressed air do not prevent any necessary development, however bold, of railway transport. On condition, naturally, that the brake is treated in the same liberal way as traction and comfort requirements, which should be its of right, seeing that it is the guarantee of safety.

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# MONTHLY BIBLIOGRAPHY OF RAILWAYS<sup>(1)</sup>

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- 1961** 347 .763  
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- 1961** 621 .314  
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- 1961** 621 .316  
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- 1961** 621 .311  
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- 1961** 621 .313  
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- 1961** 621 .316  
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- 1961** 656 .253  
Signal und Draht, April, S. 49.  
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- 1961** 656 .257  
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- 1961** 656 .225  
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1961 621 .338 (42)

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1961 621 .438

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1961 621 .314

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1961 621 .436 .72 (43)

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1961 621 .33

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1961 621 .133 .1

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1961 625 .13 (42)

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1961

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1961

621 .431 .72 (42)

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1961

656 .2 (41)

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New look for Irish Transport. (3 000 words & figs.)

### Japanese Railway Engineering. (Tokyo.)

1961

656 .212 (52)

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YUKIO TANAKA and MINORU HARADA. — A theory of efficiency marshalling yards. — New type of track layout in herringbone pattern. (1 800 words & figs.)

1961

621 .131 .1

Japanese Railway Engineering, March, p. 7.

YUKIO SEKIKAWA. — Adhesion characteristics of locomotives. (1 600 words & figs.)

1961

621 .338 (52)

Japanese Railway Engineering, March, p. 11.

KUSUO MIYAHARA. — Scientific management in repairing process of electric railcars. (1 800 words & figs.)

- 1961** **656** .223 (52)  
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**KEISUKE TAKEDA.** — **Car operation by JNR.**  
(1 900 words & figs.)

### Modern Railroads. (Chicago.)

- 1961** **625** .172 (73)  
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**MYERS (E.T.).** — **GN turns to smoothing gangs.**  
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- 1961** **621** .392 (73) & **625** .144 .1 (73)  
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- 1961** **656** .225 (42)  
Modern Transport, March 4, p. 13.  
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- 1961** **625** .41  
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**Railborne air rider.** — **Ford Levacar project discussed.**  
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- 1961** **621** .33 (54)  
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- 1961** **656** .2 (52)  
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- 1961** **621** .431 .72 (6)  
Modern Transport, March 18, p. 22.  
**Locomotive altitude tests.** From sea level to 9 000 ft. on E.A.R. (700 words & figs.)

- 1961** **625** .1 (0) (51)  
Modern Transport, March 18, p. 23.  
**China's railway programme.** (800 words.)

- 1961** **656** .2 (42)  
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**IBBOTSON (L.W.).** — **Competitive freight operation.**  
**The riddle of reliability.** (4 200 words.)

- 1961** **625** .13 (42)  
Modern Transport, April 1, p. 3.  
**New tunnelling techniques.** (1 000 words & figs.)

### The Oil Engine. (London.)

- 1961** **621** .431 .72 & **625** .214  
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**BEAZLEY (R.T.).** — **Rail engine lubricant purification.**  
(600 words & figs.)

- 1961** **621** .431 .72 (42)  
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**Experiences in the Eastern Region — Success with the Brush-Mirrlees type-2 locomotives.** (1 200 words & figs.)

- 1961** **656** .2 (42)  
The Oil Engine, May, p. 18.  
**The Railway Modernization Conference.** (1 600 words & figs.)

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- 1961** **656** .22 (73)  
Railway Age, March 13, p. 16.  
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- 1961** **625** .241 (73)  
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**Three RRs get new coil cars.** (800 words and figs.)

- 1961** **625** .143 .3  
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**What today's heavier wheel loads are doing to your rails.**  
(3 200 words & figs.)

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- 1961** **625** .13 (42)  
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**Strengthening St. Julians Usk river bridge.** (600 words & figs.)

- 1961** **656** .25  
The Railway Gazette, March 31, p. 362.  
**Koffer system of automatic train control.** (1 000 words & figs.)

- 1961** **656** .25 (42)  
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**Re-signalling of London Transport lines at Barking.**  
(2 200 words & figs.)

- 1961** **385** .4 (42)  
The Railway Gazette, April 7, p. 391.  
**The research organisation of the British Transport Commission.** (1 200 words.)

- 1961** **621** .392 (42)  
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**Weld examination by X-ray on Western Region.** (600 words & figs.)

- 1961** **625** .143 .5  
The Railway Gazette, April 7, p. 395.  
**Heavy-duty rail clips with cast-iron baseplates.** (1 600 words & figs.)

1961 621 .431 .72 (42)  
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Hydro-mechanical transmissions for dual-purpose locomotives. (1 600 words & figs.)

1961 625 .215  
The Railway Gazette, April 21, p. 446; May 12, p. 538.  
KOFFMAN (J.L.). — Carriage and railcar bogies, their design and development. II-III. (2 400 words & figs.)

1961 625 .172 (42)  
The Railway Gazette, April 21, p. 450.  
BOOTH (R.G.). — Modernisation and the permanent way in the North Eastern Region. (2 200 words & figs.)

### Diesel Railway Traction. (London.)

1961 625 .234 (71)  
Diesel Railway Traction, March, p. 120.  
Canadian train-heating cars. (600 words & figs.)

1961 625 .234  
Diesel Railway Traction, March, p. 123.  
Clayton train-heating boiler. (800 words & figs.)

1961 621 .431 .72 (471)  
Diesel Railway Traction, March, p. 125.  
Large locomotives in Finland. (1 800 words & figs.)

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1961 621 .438 (73)  
Railway Locomotive and Cars, April, p. 24.  
U.P. 8500 HP turbines give good performance. (1 000 words & figs.)

1961 621 .431 .72 (73)  
Railway Locomotive and Cars, April, p. 40.  
EMD field loop can be eliminated. (1 200 words & figs.)

### Railway Track and Structures. (Chicago.)

1961 625 .172 (73)  
Railway Track and Structures, March, p. 54.  
Tie-renewal cost on long bridge cut nearly 75 per cent by conveyor. (600 words & figs.)

1961 625 .172 (73)  
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What GN gains from central M/W repair shop. (2 400 words & figs.)

1961 625 .172 (73)  
Railway Track and Structures, April, p. 30.  
Introducing sand tamping. (1 200 words & figs.)

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1961 625 .28  
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New European motive power. (1 200 words & figs.)

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#### Ferrocarriles y Tranvías. (Madrid.)

1960 625 .162  
Ferrocarriles y Tranvías, vol. 26-XII, nº 304, p. 318.  
NOGUES CAIZ (J.). — En torno al problema de los pases a nivel. (4 000 palabras.)

1960 347 .762  
Ferrocarriles y Tranvías, vol. 26-XII, nº 304, p. 326.  
SANCHEZ GAMBORINO (F.-M.). — El derecho de los eventuales usuarios a la prestación de los servicios de transportes. IV. (Continuará.) (1 500 palabras.)

1960 621 .33 (42)  
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BROUGHALL (J.A.). — Pruebas del sistema de electrificación a 50 Hz en los Ferrocarriles Británicos. (700 palabras.)

#### Revista de Obras Públicas. (Madrid.)

1961 691  
Revista de Obras Públicas, abril, p. 213.  
LOPEZ CASADO (F.). — Cálculo de la carga de rotura de un hormigón en función de su módulo de elasticidad. (1 000 palabras & fig.)

### In Hungarian (= 494 .511).

#### Közlekedéstudományi Szemle. (Budapest.)

1959 656 .2 (06 = 494 .511)  
Közlekedéstudományi Szemle, novembre, p. 496.  
SEREDIN (A.S.). — Le plan perspectif des recherches scientifiques communes des Chemins de fer participant à l'OSSHd (OCCF). (3 000 mots.)

1959 656 = 494 .511  
Közlekedéstudományi Szemle, novembre, p. 501.  
KÁNYA (E.). — Calcul de la rentabilité dans le domaine du développement complexe des diverses branches de transport. (6 500 mots & tableaux.)

1959 656 = 494 .511  
Közlekedéstudományi Szemle, novembre, p. 515.

TURÁNYI (I.). — Sur le **problème du rendement** dans le développement complexe des diverses branches de transport. (6 900 mots & fig.)

1959 656 = 494 .511  
Közlekedéstudományi Szemle, novembre, p. 525.

CZÉRE (B.). — Les problèmes scientifiques du **développement complexe des diverses branches de transport**. (5 100 mots.)

1959 656 .2 = 494 .511  
Közlekedéstudományi Szemle, décembre, p. 537.

NÉMETH (J.). — **Tâches de développement pour les Chemins de fer**. (6 200 mots & fig.)

### In Italian.

#### Alluminio. (Milano.)

1961 625 .13  
Alluminio, marzo, p. 149.  
**Armature telescopiche di lega leggera per il rivestimento di gallerie**. (500 parole & fig.)

#### Giornale del Genio Civile. (Roma.)

1961 62 (01  
Giornale del Genio Civile, febbraio-marzo, p. 125.  
CICALA (P.). — **Presentazione geometrica delle relazioni fondamentali d'elastoplasticità**. (5 000 parole & fig.)

1961 721 .4  
Giornale del Genio Civile, febbraio-marzo, p. 148.  
GENTILONI SILVERJ (D.). — **Volte cilindriche antoportanti**. Confronto di soluzioni equilibrate a trave e a volta. (6 000 parole, tabelle & fig.)

#### Ingegneria Ferroviaria. (Roma.)

1961 621 .3  
Ingegneria Ferroviaria, marzo, p. 201.  
RIGHI (R.). — Un metodo grafico-numerico per la semplificazione ed il disegno dei circuiti di **commutazione combinatori a contatti**. (5 000 parole & fig.)

1961 621 .335  
Ingegneria Ferroviaria, marzo, p. 211.  
ANTONUCCI (A.). — **Il comando multiplo sui locomotori a corrente trifase ad alta velocità**. (3 000 parole & fig.)

1961 624  
Ingegneria Ferroviaria, marzo, p. 220.  
D'ALESSANDRO (G.). — **Linee di influenza per vincoli mobili**. (1 600 parole, tabelle & fig.)

1961 621 .31  
Ingegneria Ferroviaria, marzo, p. 234.  
GUIDI BUFFARINI (G.) & SCHINAIA (C.). — Ripartizione di massima economia delle **alimentazioni delle reti di trasporto**. (4 000 parole & fig.)

1961 656 .2 (4)  
Ingegneria Ferroviaria, marzo, p. 245.  
CUTTICA (A.). — **Aspetti del problema ferroviaria dell' Europa Occidentale**. (2 500 parole.)

1961 656 .122  
Ingegneria Ferroviaria, marzo, p. 249.  
PANZARASA (C.). — **La teoria marginalista ed i prezzi di trasporto**. (2 000 parole.)

#### Rivista di Ingegneria. (Milano.)

1961 691  
Rivista di Ingegneria, aprile, p. 381.  
FERRARI (S.). — **Caratteristiche generali e applicazioni degli inibitori organici della corrosione**. (3 000 parole & tavole.)

### In Netherlands.

#### De Ingenieur. (Den Haag.)

1961 654  
De Ingenieur, n° 15, 14 april, p. E. 27.  
**Multitooncode-signaleringsysteem**.  
I. Inleiding tot het systeem, door W.C. de VRIES. (700 woorden.)  
II. Algemene grondslagen van het systeem, door G.J. KAMERBEEK. (2 500 woorden & fig.)

1961 691  
De Ingenieur, n° 16, 21 april, p. Bt. 49.  
WULKAN (E.K.H.). — **De oppervlaktebehandeling van beton**. (5 000 woorden, tabellen & fig.)

#### Spoor- en Tramwegen. (Den Haag.)

1961 385 (06 .4 (492)  
Spoor- en Tramwegen, n° 8, 20 april, p. 125.  
HAUER (J.M.). — **Internationale Tentoonstelling te Elst**. (2 000 woorden & fig.)

1961 621 .431 .72 (492)  
Spoor- en Tramwegen, n° 8, 20 april, p. 131.  
MAURER (J.J.), MOOLHUIZEN (Chr.) en VAN OMME (N.). — **De dieselelektrische drierijtuigstellen serie 111-125 van de N.S. (Slot.)** (1 000 woorden & fig.)

1961 656 .2 (931)  
Spoor- en Tramwegen, n° 8, 20 april, p. 133.  
VAN BIJNEN (J.). — **De spoorwegen van Nieuw-Zeeland**. VI. (1 000 woorden & fig.)

- 1961** 656 .2 (42)  
Spor- en Tramwegen, n° 8, 20 april, p. 135.  
Weinig enthousiasme voor nieuwe Britse spoorweg-  
plannen. (2 000 woorden.)
- 1961** 656 .213  
Spor- en Tramwegen, n° 9, 4 mei, p. 144.  
VAN LIESHOUT (J.) en VAN RIJN (J.). — Enige  
aspecten van een eigen spoorverbinding. (1 600 woorden  
& fig.)
- 1961** 656 (73)  
Spor- en Tramwegen, n° 9, 4 mei, p. 147.  
De concurrentiepositie van de Amerikaanse spoor-  
wegen. (2 500 woorden.)

In Polish (= 491 .85).

Przegląd Kolejowy Drogowy. (Varsovie.)

- 1959** 625 .142 .2 = 491 .85  
Przegląd Kolejowy Drogowy, octobre, p. 183.  
ADAMCZYKOWA (K.). — Sur les propriétés bio-  
logiques de l'huile fongicide « D » pour l'imprégnation  
complémentaire des traverses. (1 700 mots & fig.)
- 1959** 625 .13 = 491 .85  
Przegląd Kolejowy Drogowy, octobre, p. 188.  
SIDORENKO (A.). — Les devoirs de la surveillance  
technique pendant les travaux aux ponts. (1 200 mots.)
- 1959** 625 .144 .4 = 491 .85  
Przegląd Kolejowy Drogowy, novembre, p. 201.  
LANKIEWICZ (J.) et BAK (M.). — Remplacement  
continu de la superstructure en se servant de bases fixes de  
montage. (2 500 mots & fig.)
- 1959** 625 .143 = 491 .85  
Przegląd Kolejowy Drogowy, novembre, p. 209.  
SZEWCZYK (H.). — L'application d'un dispositif  
à dresser les rails dans la voie avec longues barres est-elle  
indispensable ? (1 400 mots.)
- 1959** 625 .142 .4 = 491 .85  
Przegląd Kolejowy Drogowy, novembre, p. 214.  
CICKIEWICZ (Z.). — Machine type « BL-3 » pour la  
production de traverses en béton armé. (900 mots & fig.)
- 1959** 625 .144 .4 (437) = 491 .85  
Przegląd Kolejowy Drogowy, décembre, p. 221.  
WARASZKIEWICZ (J.). — Etude du travail des  
bourreuses électriques en Tchécoslovaquie. (2 100 mots  
& fig.)
- 1959** 625 .144 = 491 .85  
Przegląd Kolejowy Drogowy, décembre, p. 227.  
DUBIENSKI (B.). — Nouveaux principes de construc-  
tion de l'infrastructure, illustrés par des données numé-  
riques. (800 mots & tableaux.)

Przegląd Kolejowy Elektrotechniczny. (Varsovie.)

- 1959** 625 .233 (438) = 491 .85  
Przegląd Kolejowy Elektrotechniczny, novembre, p. 305.  
PIASTOWSKI (J.). — Problème de l'alimentation  
électrique des voitures à voyageurs en URSS. (2 100 mots  
& fig.)
- 1959** 656 .251 = 491 .85  
Przegląd Kolejowy Elektrotechniczny, novembre, p. 309.  
GORECKI (H.). — Circuits d'alimentation et d'en-  
clenchement des entraînements par moteurs électriques  
des signaux d'avertissement à trois sections. (1 500 mots  
& fig.)
- 1959** 625 .23 : 621 .3 = 491 .85  
Przegląd Kolejowy Elektrotechniczny, novembre, p. 314.  
GODWOD (J.). — Dispositifs électro-acoustiques dans  
les voitures à deux étages. (1 300 mots & fig.)
- 1959** 656 .257 = 491 .85  
Przegląd Kolejowy Elektrotechniczny, décembre, p. 337.  
KOSINSKI (R.). — Relais neutres dans les équipe-  
ments de commande centralisée. (2 500 mots & fig.)
- 1959** 654 = 491 .85  
Przegląd Kolejowy Elektrotechniczny, décembre, p. 344.  
LEITENBERGER (W.). — Transmission de télé-  
grammes à contenu identique à plusieurs destinataires.  
(1 300 mots & fig.)
- 1959** 621 .332 = 491 .85  
Przegląd Kolejowy Elektrotechniczny, décembre, p. 347.  
KOZAKIEWICZ (J.). — Endommagements des iso-  
lateurs de traction causés par la corrosion des griffes.  
(1 000 mots & fig.)
- Przegląd Kolejowy Przewozowy. (Varsovie.)
- 1959** 656 .213 = 491 .85  
Przegląd Kolejowy Przewozowy, août-septembre, p. 210.  
MAJEWSKI (S.). — L'organisation et les caractéristi-  
ques du travail de transport ferroviaire dans les ports.  
(1 900 mots & fig.)
- 1959** 656 .232 = 491 .85  
Przegląd Kolejowy Przewozowy, août-septembre, p. 215.  
BLOTKO (K.). — Combien une mise en marche d'un  
train nous coûte-elle ? (1 200 mots & tableaux.)
- 1959** 656 .223 .2 = 491 .85  
Przegląd Kolejowy Przewozowy, août-septembre, p. 218.  
ZAJFRYD (M.). — Pour une accélération de la circu-  
lation des wagons. (1 800 mots & tableaux.)
- 1959** 656 .223 .2 = 491 .85  
Przegląd Kolejowy Przewozowy, octobre, p. 252.  
DABROWSKI (K.). — Modifications dans la gestion  
des wagons à marchandises. (2 700 mots.)
- 1959** 656 .225 = 491 .85  
Przegląd Kolejowy Przewozowy, octobre, p. 264.  
SWIDERSKI (F.). — Livraison et prise des charge-  
ments dans les gares ferroviaires. (1 300 mots.)

1959 656 .222 .6 = 491 .85  
Przegląd Kolejowy Przewozowy, novembre, p. 276.  
DUL (M.). — *Horaire international des trains de marchandises.* (LIM). (1 200 mots.)

1959 656 .2 (51) = 491 .85  
Przegląd Kolejowy Przewozowy, novembre, p. 278.  
DOWIATT (W.). — *Réseau ferroviaire de la République populaire de Chine.* (1 900 mots & fig.)

### In Portuguese.

Gazeta dos Caminhos de ferro. (Lisboa.)

1961 656 .2 (82)  
Gazeta dos Caminhos de ferro, n° 1760, 16 de Abril, p. 53.  
de BRITO LEAL (C.). — *Os Caminhos de ferro nos países longínquos. A rede ferroviária da Argentina.* (2 000 palavras & mapa.)

Técnica. (Lisboa.)

1961 691  
Técnica, Fevereiro, p. 303.  
OSORIO DE ROCHA E MELO (J.). — *Conceitos actualizados sobre a moenda do cimento.* (4 000 palavras quadros & fig.)

### In Russian (= 491 .7).

Avtomatica, Telemekhanika i Svias. (Moscou.)

1959 656 .25 (51) = 491 .7  
Avtomatica, Telemekhanika i Svias, octobre, p. 4.  
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CHICHLYAKOV (A.W.). — *Amplificateur ALS avec des diodes cristal pour locomotives.* (1 700 mots & fig.)

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YÉRCHOV (I.M.), IVANOVA (W.I.) et BROUNITCH (I.S.). — *Les constructions en béton armé doivent être de longue durée.* (2 800 mots.)

1959 621 .335 = 491 .7  
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SSORINE (N.A.). — *Schéma électrique de la locomotive électrique série VL 23.* (2 900 mots, tableaux & fig.)

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MEREJKO (W.Gu.). — *La mécanisation complexe et l'automatisation des processus de production dans les dépôts de locomotives.* (2 100 mots.)

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PANFIL (L.S.) et WORONYÉNKO (A.A.). — *Méthode améliorée pour la fusion de la glace sur les fils de contact des caténaires.* (700 mots & fig.)

1959 621 .333 = 491 .7  
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ALKHANOV (A.S.). — *Commande automatique de postes de sectionnement de la ligne de contact.* (1 200 mots & fig.)

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PRITZ (A.K.). — *Quelques propositions d'amélioration de la commutation des moteurs de traction dans les locomotives électriques.* (2 100 mots & fig.)

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**OSIPOV (S.I.). — La locomotive électrique TchS2 pour**  
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**SSOKOLOV (A.W.). — Méthodes d'abaissement du**  
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**1961** **691** = 91 .882  
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 fig.)

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